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## BOILER EXPLOSIONS—THE CAUSE AND THE REMEDY.

By THOMAS KAYS.

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SINCE the introduction of steam as a motive power, and in the face of continuous investigation, the cause of steam boiler explosions has, until recently, remained a profound mystery. The theories of explosions were numerous. The most prevalent were "low water," "hot iron," "high pressure," "mere escape of steam," "superheated steam," "electrical," "gaseous," and the "spheroidal."

The theory most generally accepted was that of low water. This theory was in conflict with facts as established by unquestionable evidence, and therefore many refused to accept it.

The other theories were alike erroneous, and the result was much confusion of opinion upon the subject. The real cause was discovered by Daniel T. Lawson, of Wellsville, Ohio. He conceived the idea, and has fully demonstrated the fact, that water is an explosive, and that all steam boiler explosions are caused by the explosion of superheated water; that the explosion occurs upon a sudden reduction of pressure, followed by a sudden check to the exploding water, the result of which is a striking blow far in excess of the tensile strength of boilers.

The Lawson theory, briefly stated, is this:

The only explosive material about a steam boiler is water, and water, when superheated, which can be done only under pressure, will explode upon a sudden removal of that pressure, with a force quite equal to that of dynamite.

The boiling-point of water varies with pressure. In a vacuum, water boils at 70° sensible heat. Under atmospheric pressure it boils at 212°, and cannot be made hotter unless confined under additional pressure, because the escaping steam carries off the heat as fast as fire can impart it. In a steam boiler under 10 lbs. pressure it boils at 241°; 50 lbs., 300°; 100 lbs., 340°; 200 lbs., 389°.

Water when heated to the boiling point requires 966° additional heat to change it from the state of water to the state of steam. This change is substantially instantaneous at all pressures. As each molecule of water absorbs the last of the 966° it instantly explodes into steam. As the last degree is absorbed cohesion is overcome and repulsion becomes the predominant power.

The change of steam to water is also instantaneous. Steam remains in its new state only so long as it retains the 966° of latent heat, and the moment it is at full volume, with only 212° of sensible heat, parts with one of these degrees of latent heat, it returns to water.

The explosion of water is similar to that of gunpowder, in some respects, but different in others. Each grain of gunpowder passing from the solid to the gas-

eous state explodes when it has absorbed a certain degree of heat. So with water. Each molecule of water, at the instant it has absorbed 966° of heat above the boiling point, explodes and passes from water into steam. The expansive quality of the two is different, powder increasing in bulk 800 times, while water increases 1,720 times. The mode of exploding and the general result, large and sudden increase of bulk, are similar. In other respects they differ widely; the explosion of powder is by chemical action, the explosion of water is by physical change only.

Water differs widely from powder and all other explosives in another remarkable particular. Only a portion of the water may explode—one molecule, the half, or the whole mass. These various amounts in exploding produce results ranging from violent explosions to mild ruptures and the safe operation of the boiler.

When a grain of powder starts to go from the solid to the gaseous state no power can stop it. It may be confined, but combustion, once begun, goes on to completion. So with a molecule of water. It may be put under such pressure that it will not fully expand, but, once begun, it changes its state from water to steam.

The true source of the development of the great destructive power in a steam boiler is the sudden *concentration* of the sensible heat in the water above 212° (or above 70°, in case of a vacuum caused by the condensation of steam) into a part of the molecules of water passing into them the 966° necessary to change them from the state of water to the state of steam.

That the stored heat in a boiler concentrates to form steam is shown by familiar experiments.

As, for instance, causing water at less than 212° to boil by placing it in a vacuum; or, by merely condensing the steam overheated water in a bottle.

Again, take a steam boiler under pressure of 100 lbs., and a corresponding temperature of 340°. Remove the fire and the formation of steam will cease. After a short time raise the safety valve, and the water will begin to boil and generate and give off steam continuously as the pressure is reduced, until a temperature of 212° is reached, and enough steam will be thus generated and blown off to fill the boiler very many times.

These tests show that the boiling point of water is lowered by simply diminishing the pressure. They show this, and also show the true theory of boiler explosions. They prove in the most conclusive manner that the sensible heat above 70° stored in the water concentrates in a part of the molecules of water, giving to them the 966° necessary to change them into steam. The water ceases to boil, no heat is applied, and by merely reducing the pressure the water again boils. The 966° above the boiling point necessary to cause ebullition are not absorbed from the fire at the instant the water begins to boil the second time. They are already stored up in the water.

Take a boiler containing 10,000 lbs. of water at a pressure of 200 lbs. and a corresponding temperature of 389°. Suddenly reduce the pressure to 50 lbs. per square inch, under which pressure water explodes at 300°. There are stored in each of the 10,000 lbs. of water 80° of sensible heat above the exploding point —in the aggregate 800,000 thermal units, enough to convert 921 lbs. of this superheated water into steam. In an instant these 89° of sensible heat in each pound of water are absorbed by the molecules of water at the surface and for a considerable depth, and suddenly these 921 lbs. of superheated water explode into steam.

Thus, it will be seen that there is sufficient destructive power stored in the boiler when thus put in action to cause an explosion. If the reduction of pressure caused by the withdrawal of steam be moderate, and such draught be continuous and uniform, there will be no danger; but if the draught is considerable in quantity and instantly checked, the nascent steam thus suddenly formed and thus suddenly checked will give an *impact* or *striking blow* upon the shell of the boiler, the aggregate force of which is equal to the weight of the water before it passed into nascent steam multiplied by the square of the velocity with which it strikes.

The instantaneous check to the exploding water acts upon the boiler with the same effect as that produced by quickly closing the valve of a watermain. In the

one case it is the weight of the falling water, and in the other it is the force of exploding water, but the striking effect of the blows is the same, and is measured by the same rule.

Take a boiler 48 inches in diameter, 19 feet long, and place in it 10,000 lbs. of water. Then raise the temperature to 400°, and the corresponding pressure will be about 235 lbs. About $\frac{1}{200}$ part of the water, or 50 lbs., passes into steam, occupying the balance of the space of the boiler, about 86 cubic feet. The temperature is 188° above 212°. The amount of sensible heat, above 212°, stored in the remaining 9,950 lbs. of water is 1,870,600 thermal units, equivalent in mechanical energy to 1,444,103,200 foot-pounds. Suddenly reduce the pressure from 235 lbs. to normal. At 235 lbs. it required 400° to evaporate water, at normal pressure only 212°—a difference of 188°. There are stored in the boiler 1,870,600 units of sensible heat above 212°, enough to convert about 1,936 lbs. of the remaining water into steam, which would occupy, under 235 lbs pressure, about 3,000 cubic feet of space. Rating the velocity of the nascent steam at one-half the velocity of full steam discharged into the air (1967÷2), would give a striking force of over 23,000 lbs. per square inch upon the shell of the boiler.

Again, start with a pressure of 25 lbs. (at which the Westfield exploded in New York City, in 1871), and a corresponding temperature of 269°, and only 57° above 212°, and the amount of sensible heat stored above 212° would be 567,150 thermal units. Reduce the pressure to 0, corresponding to 70°, and the 9,950 lbs. of water would contain 1,980,050 thermal units, sufficient to convert 2,049 lbs. of water into steam. Rating the weight of the water and the velocity of the nascent steam as in the last case, this would give a striking blow of over 24,000 lbs. per square inch.

Take a boiler half full of water, under a pressure of 200 lbs. and at 389°, and suddenly inject into the steam space a quantity of cold water. Condensation is instantaneous. Instantly the superheated water at 389° is in a vacuum where it will explode at 70°. Under these circumstances a large portion of the water will explode into steam, and, whether one-quarter, one-half, or the whole, the striking force will be sufficient to tear into shreds any boiler ever made.

If the withdrawal of steam is slight, even if followed by a sudden check, no damage ensues with boilers of the usual tensile strength; but if the withdrawal be considerable and the check instantaneous, an explosion follows. With the varying degrees of draught and sudden check come violent explosions and mere rupture.

The distinction between *rupturing* and *exploding* is generally overlooked. When a boiler gives way at a weak point, resulting in damage, it is often called an explosion. When ruptured by mere pressure, the force exerted upon the shell being gradual and uniform, the weak point yields while the balance remains intact. Serious damage may result, but a uniform and unobstructed flow of steam never produces the phenomenon properly called an "explosion."

With an explosion the actual destructive force exerted is not measured by the tensile strength of the boiler nor by the regular pressure of the steam. The force is far in excess of either—five, ten, and often twenty times as great, an immense aggregate concussive and destructive force that tears asunder the weak and the strong parts at the same instant and demolishes everything within a large radius.

All writers on steam boiler explosions, in trying to account for their violence, have made the mistake of commencing the calculation at a point of time after the rupture has commenced. The fact is, there is violent internal action at the instant preceding the actual rupture of the boiler, and the rupture is the result of such action Rupture may be caused by the mere pressure of steam, but it is usually caused by an internal concussive force. It is certainly illogical to say that boilers are ruptured or burst by mere pressure while working with a pressure of only one-fifth their actual tensile strength.

The rational solution of a steam boiler explosion is this:

The water in the boiler under pressure is superheated, and possesses a highly expansive power. Upon a sudden removal of the pressure, without a corresponding reduction of the temperature,

it starts into violent evaporation. This mass of nascent steam is checked by coming in contact with the solid and unyielding shell of the boiler. The result is that the aggregate force of this nascent steam strikes every square inch of the shell of the boiler at the same instant and with the same force, and with a power far in excess of the tensile strength of the boiler; and, moreover, this force is augmented at the instant the shell gives way by an immense reserve power caused by the further evaporation of the water in the boiler.

This theory is in unison with natural laws, and upon it every explosion, bursting or rupture of steam boilers can be fully explained, and cannot be upon any other.

### Remedy.

Mr. Lawson, having discovered the cause, naturally turned toward the remedy, which is a simple one, and consists in the construction of a boiler with a partition plate, or diaphragm, dividing it into two compartments, the lower containing the water, and the upper containing steam only. The steam passes from the lower to the upper compartment through numerous small perforations and a number of small valves in the diaphragm. The aggregate openings of the valves and perforations should be less than the valve through which the engine is supplied. By this means the pressure upon the surface of the superheated water is kept approximately uniform, and all sudden explosions of any dangerous quantity of water into steam and consequent striking blows are avoided.

The diaphragm extends the length and width of the boiler, and is firmly riveted to the sides and ends thereof, as shown by figures 1 & 2. It may be circular or flat, and so located as to cut off about two-thirds of the usual steam space.

The perforations and valves vary with boilers of different size. The aggregate area of all the perforations and valve orifices should be about ten per cent. less than the area of the steam port. In ordinary-sized boilers there should be one perforation of one-quarter of an inch in diameter to each horse-power, rating ten square feet of heating surface to the horse-power, and such number of valve orifices of about two inches in diameter as to make up the balance of the aggregate area.

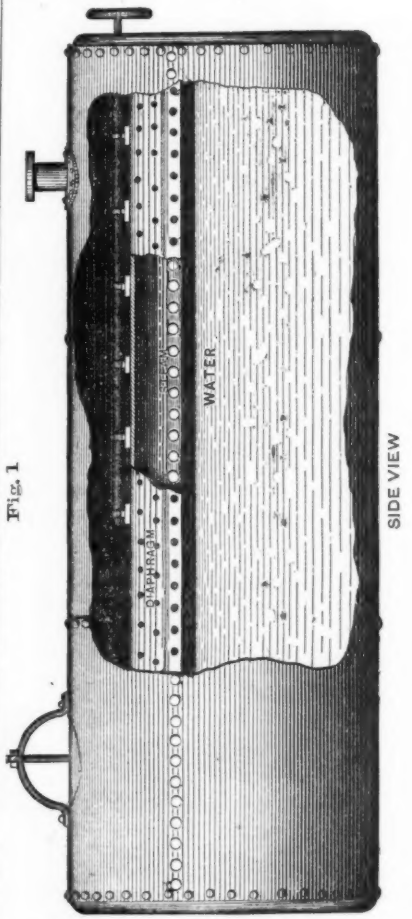



Fig. 1

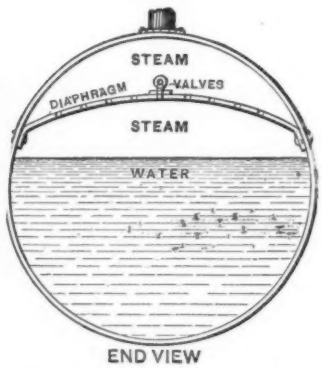
This lessening of the aggregate area ten per cent. below that of the steam port will give a very slight diminution of pressure in the engine with steam working at full stroke, but will practically give full pressure at every other point of cut-off.

There must be two steam gauges used, one connected with the water space below, and one with the steam space above, the diaphragm.

When the boiler is set and ready for use such small valves should be closed.

As the steam is generated and the engine put in operation at its full capacity, any additional steam required is obtained by gradually and partially opening such valves until the required amount is liberated and ascertained, when such valves are set, and need but little further attention. In thus arranging such valves particular attention should be paid to the steam gauges. The valves should be opened only to that extent at which the pressure upon the superheated water in the lower compartment, as shown by the gauges, remains approximately uniform with that in the upper, with the engine in full operation. Thus arranged, any unusual and sudden withdrawal of steam from the upper chamber is attended with no possible danger.

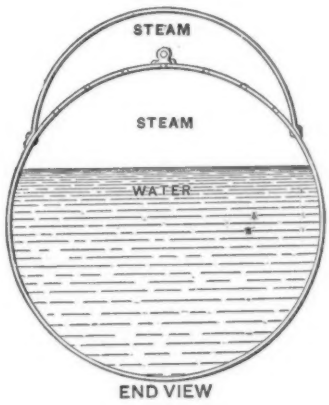
Fig. 2




Boilers thus constructed and arranged are protected against explosions, whether the water wholly or partially fills the water compartment. If wholly filled a sudden reduction of pressure in the steam compartment can instantly affect only the surface of the water to the extent of the aggregate area of the perforations and valve orifices, and no dangerous quantity of water can be thus exploded. As the pressure upon the water below the diaphragm is thus slightly reduced, small portions of the water pass into steam and maintain uniformity of pressure.

If the water should get low, thus accumulating an unusual quantity of steam below the diaphragm, there can be no danger of an explosion. The discharge of steam from the ordinary boiler into the empty pipes and cylinder upon the sudden opening of the valves, is at a velocity of over 100,000 feet per minute, and for an instant there is a great reduction of pressure upon the surface of the superheated water. This cannot occur with the Lawson diaphragm in a boiler. With it the passage of steam from the water compartment below the diaphragm to the steam space above it is limited to that quantity used by the engine with the piston moving at the rate of, say, 600 feet per minute, and cannot exceed this precise amount to any great extent, although the steam may, from some unusual cause, be temporarily rushing from the steam space above the diaphragm fifty times as fast. The diaphragm limits the quantity of steam discharged from the water compartment to the exact amount necessary to drive the engine in full operation, and the liberation of this amount at such uniform rate can be attended with no possible danger.

Fig. 3




The Lawson diaphragm is to the steam boiler what the air chamber is to the hydraulic ram. It performs a similar, but much more important, function. The elasticity of the air moderates the otherwise solid blows of water upon the pipes; the diaphragm preserves uniformity of pressure upon the water, and thus prevents its explosion and the consequent violent and irresistible concussive blows upon the shell of the boiler.

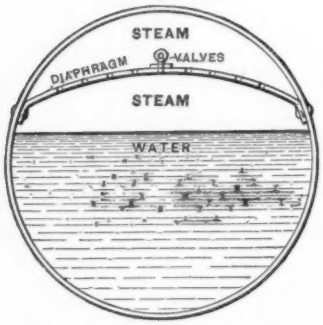
Explosions are thus prevented, not by extra strong boilers, but by preventing the occurrence of the cause. Boilers thus constructed can be safely operated at a pressure closely approaching their actual tensile strength.

The invention is applicable to every style of boiler, and can be readily applied, internally or externally to new or old boilers.

Figs. 1 to 7 fully illustrate the invention. Figs. 1 and 2 show an internal, and Figs. 3 to 7 an external application. Fig. 3, moderate pressure; Figs. 1, 2 and 5, high pressure, and Figs. 6 and 7, very high pressure.

Up to June, 1881, no person had ever intentionally exploded a boiler in accordance with any certain theory or plan, or with a knowledge of the true cause.

Fig. 4.



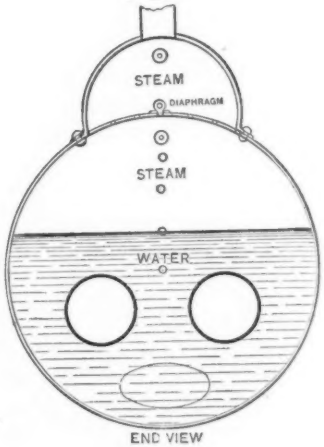

On the 16th of that month Mr. Lawson, at Munhall, near Pittsburgh, Pa., publicly tested his theory, and exploded a boiler of the ordinary style having a tensile strength of 768 lbs., at a pressure of but 290 lbs., being 478 lbs. less than the actual strength of the iron.

The experiment was made by suddenly discharging a considerable quantity of steam at 290 lbs. from the boiler into a closed cylinder, the explosion occurring the instant the cylinder was filled.

In March, 1882, he made further experiments at the same place under the inspection of a commission of U. S. engineers, appointed by the Secretary of the Treasury, and fully tested a boiler with his invention attached.

The boiler having the Lawson diaphragm, and being 30 inches in diameter, with only 18 inches of water, running down to 11 inches, 4 inches below the fire line, stood every test of rapid escape and sudden check of steam up to a pressure of 300 lbs., without the slightest injury. The same boiler, with the center of the diaphragm removed, reducing it to the ordinary-style boiler, with 22 inches of water, 7 inches above the fire line, was exploded at a pressure of only 235 lbs., 65 lbs. less than the boiler had withstood with Lawson's device, under precisely the same circumstances, except as to the quantity of water.

Fig. 5




### High Pressure.

This discovery and invention remove all obstacles to the use of high pressure.

With immunity against explosion, higher pressure is safely secured, and with it greater power and economy attained.

The invention has other advantages of great importance.

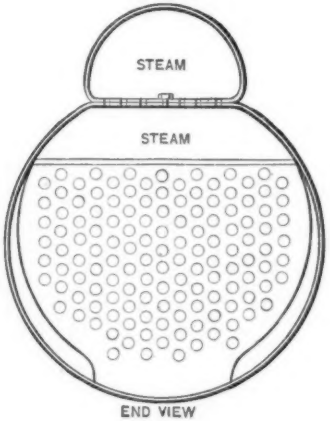
### Dry Steam.

It produces dry steam, and prevents "foaming," "priming," or "entrainment."

The cause of these evils is that a large quantity of steam taken suddenly from a boiler at one point greatly reduces the pressure upon the water immediately under the point of exit, while the full pressure of the steam remains upon the surface of the water at every other point, and the result is that portions of the water are constantly forced out with the steam into the cylinder.

At each half stroke of the piston the sudden withdrawal of the steam from the boiler *at one point* in large quantities, while in direct contact with the surface of the water, decreases the pressure upon the water nearest the point of exit, causing it to rise up in the shape of a cone, while at all other points it is depressed below its former level, and by the sudden withdrawal of the steam in this manner, the pressure upon the water is at every half stroke of the piston reduced below the boiling point of the previous instant. The successive half strokes of the piston are followed by the cut-off of steam, which changes the pressure upon the water. This gives to the water a continual churning motion, the cone-

Fig. 6




shaped column of water rising at each half stroke and falling at each cut-off of steam, the balance of the water rising and falling correspondingly. This commotion is greatly increased by the pressure being changed at rapid intervals below the boiling-point of the water of the previous instant, thus causing the water to start into violent ebullition.

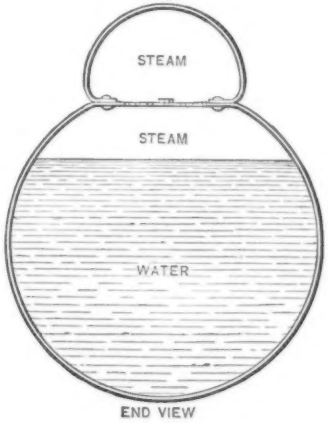
With the diaphragm, the steam passes from the lower compartment to the upper, not at one point, but in small quantities at many points; and the steam used being taken from the upper compartment, all the concussive force and intermittent pressure and motion are arrested and confined to the upper compartment, and the result is that the pressure upon the surface of the water is *uniform*; there is no rising and falling of cone-shaped columns of water, no irregular pressure, no churn-like motion to the water, no irregular and violent ebullition.

### Incrustation.

With boilers thus constructed, incrustation is wholly prevented. All foreign solid substances held in suspension or solution are separated from the water and deposited upon the diaphragm, where they do not interfere with the generation of steam and whence they can be readily removed.

This results from natural laws. All matter free to move occupies positions according to its specific gravity. Water in motion has the power of moving solids

Fig. 7




many times its own weight. Air, in only moderate motion piles up hills of sand, a substance two thousand times its own weight. Compressed steam has much greater power than air. The water and steam in a boiler have a rapid upward motion. Again, if the motion of the carrying substance is checked, the foreign matter it is carrying, if of a greater specific gravity, is dropped.

In the operation of a boiler with this device the greatest velocity of the steam is when it passes through the small orifices in the diaphragm, and the check comes when it is discharged into the upper compartment, and as the motion of the steam is checked it drops the sediment. Another law is that all sediment settles where there is the least motion.

There is still another operation constantly going on in this chamber which greatly aids in thus depositing the sediment. It is this, the steam is drawn from this chamber for use. At each cut-off of the supply of steam to the engine there is a slight intermittent motion to the steam in this chamber. At each cut-off there is a decrease in the specific gravity of the steam, resulting from the change of pressure, and this decrease of gravity and intermittent motion all tend to deposit the sediment. This boiler, therefore, with no other contrivance, thus forces the solid foreign substances in the water into the upper chamber before they have any chance to fasten themselves to the shell of the boiler.

Thus, the mystery of boiler explosions having been solved, and a perfect preventive devised, accompanied by the attainment of dry steam, absence of incrustation, and safety with high pressure, are we not upon the threshold of a new era in the use of steam?

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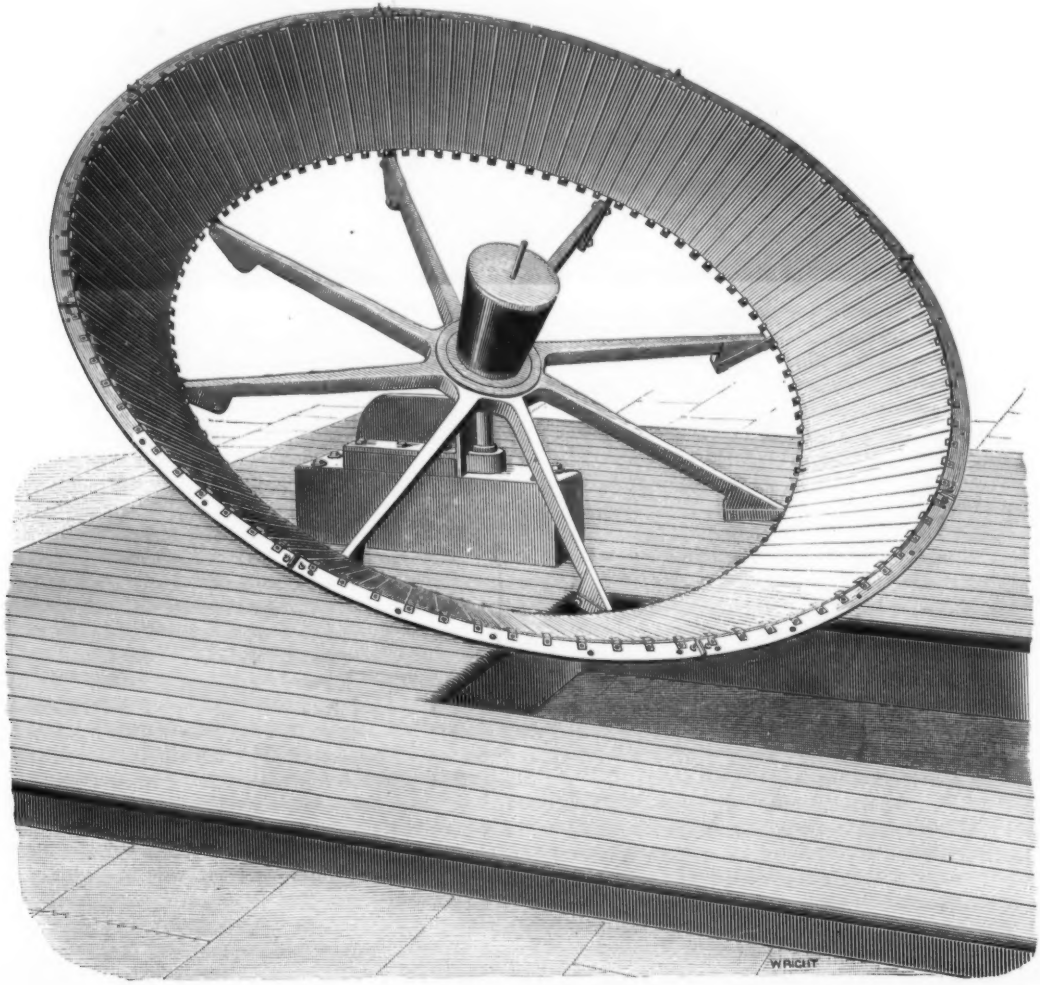
## THE TEMPERATURE OF THE SOLAR SURFACE.

By J. ERICSSON.

From "Nature."

THE power developed by the sun motor recorded in *Nature*, vol. xxix. p. 217, has established relations between diffusion and energy of solar radiation which prove that the temperature of the surface of the sun is extremely high. I have, therefore, during the summer solstice of 1884, carried out an experimental investigation for the purpose of demonstrating the temperature of the solar surface corresponding with the temperature transmitted to the sun motor. Referring to the illustrations previously published, it will be seen that the cylindrical heater of the sun motor, constructed solely for the purpose of generating steam or expanding air, is not well adapted for an exact determination of the amount of surface exposed to the action of the reflected solar rays. It will be perceived on inspection that only part of the bottom of the cylindrical heater of the motor is acted upon by the reflected rays, and that their density diminishes *gradually* towards the sides of the vessel; also that owing to the imperfections of the surface of the reflecting plates the exact course of the terminal rays cannot be defined. Consequently, the most important point in the investigation, namely, the area acted upon by the reflected radiant heat, cannot be accurately determined. I have accordingly constructed an instrument of large dimensions, a polygonal reflector (see Fig. 1), composed of a series of inclined mirrors, and provided with a central heater of conical form, acted upon by the reflected radiation in such a manner that each point of its surface receives an equal amount of radiant heat in a given time. The said reflector is contained within two regular polygonal planes twelve inches apart, each having ninety-six sides, the perimeter of the upper plane corresponding with a circle of eight feet diameter, that of the lower plane being six feet. The corresponding sides of these planes are connected by flat, taper mirrors composed of thin glass silvered on the outside. When the reflector faces the sun at right angles, each mirror intercepts a pencil of rays of 32.61 square inches section, hence the entire reflecting surface receives the radiant heat of an annular sunbeam of $32.61 \times 96 = 3130$ square inches section. It should be observed that the area thus stated is 0.011 less than the total foreshortened superficies of the ninety-six mirrors if sufficiently wide to come in perfect contact at the vertices. Fig. 2 represents a transverse section of the instrument as it appears when facing the sun; the direct and reflected rays being indicated by dotted lines. The reflector and conical heater are sustained by a flat hub and eight radial spokes bent upwards towards the ends at an angle of 45°. The hub and spokes are supported by a vertical pivot, by means of which the operator is enabled to follow the diurnal motion of the sun, while a horizontal axle, secured to the upper end of the pivot, and held by appropriate bearings under the hub, en-




Captain Ericsson's Solar Pyrometer, erected at New York, 1884.

ables him to regulate the inclination to correspond with the altitude of the luminary. The heater is composed of rolled plate iron 0.017 inch thick, and provided with head and bottom formed of non-conducting materials. By means of a screw-plug passing through the bottom

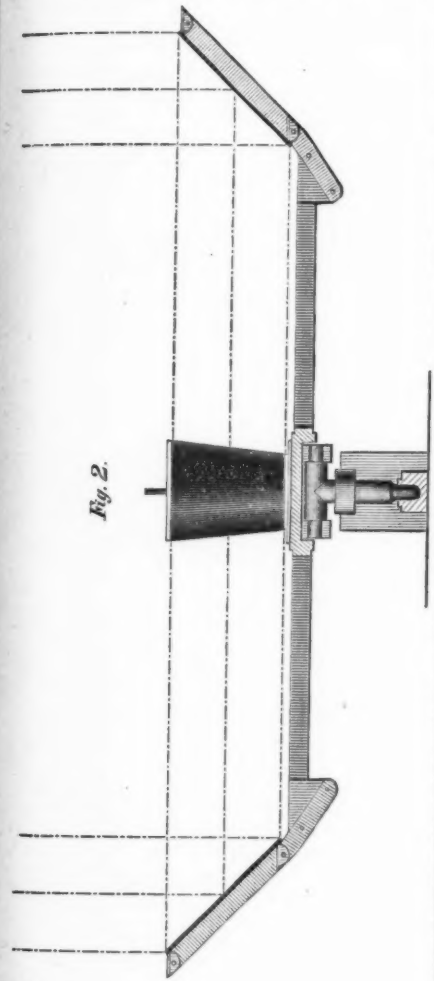


Fig. 2.

and entering the face of the hub the heater may be applied and removed in the course of five minutes, an important fact, as will be seen hereafter. It is scarcely necessary to state that the proportion of the ends of the conical heater should correspond with the perimeters of the reflector, hence the diameter of the upper end, at the intersection of the polygonal plane, should be to that of the lower end as 8 to 6, in order that every part may be acted upon by reflected rays of equal density. This condition being fulfilled, the temperature communicated will be perfectly uniform. A short tube passes through the upper head of the heater, through which a thermometer is inserted for measuring the internal temperature. The stem being somewhat less than the bore of the tube, a small opening is formed by which the necessary equilibrium of pressure will be established with the external atmosphere. It should be mentioned that the indications of the thermometer during the experiment have been remarkably prompt, the bulb being subjected to the joint influence of radiation and convection.

The foregoing particulars, it will be found, furnish all necessary data for determining with absolute precision the *diffusion* of rays acting on the central vessel of the solar pyrometer. But the determination of temperature which uninterrupted solar radiation is capable of transmitting to the polygonal reflector calls for a correct knowledge of atmospheric absorption. Besides, an accurate estimate of the loss of radiant heat attending the reflection of the rays by the mirrors is indispensable. Let us consider these points separately.

*Atmospheric Absorption.*—The principal object of conducting the investigation during the summer solstice has been the facilities afforded for determining atmospheric absorption, the sun's zenith distance at noon being only 17° 12′ at New York. The retardation of the sun's rays in passing through a clear atmosphere obviously depends on the depth penetrated; hence—neglecting the curvature of the atmospheric limit—the retardation will be as the secants of the zenith distances. Accordingly, an observation of the temperature produced by solar radiation at a zenith distance whose secant is *twice* that of the secant of 17° 12′, viz., 61° 28′, determines the minimum atmospheric absorption at New York. The result of observations conducted during a series of years shows that the maximum solar intensity at 17° 12′ reaches 66.2°

F., while at a zenith distance of 61° 28′ it is 52.5° F.; hence, minimum atmospheric absorption at New York, during the summer solstice, is 66.2°−52.5°= 13.7° F., or $\frac{13.7}{66.2}$=0.207 of the sun's radiant energy where the rays enter the terrestrial atmosphere.

In order to determine the loss of energy attending the reflection of the rays by the diagonal mirrors, I have constructed a special apparatus, which by means of a parallactic mechanism faces the sun at right angles during observations. It consists principally of two small mirrors, manufactured of the same materials as the reflector, placed diagonally at right angles to each other; a thermometer being applied between the two whose stem points towards the sun. The direct solar rays entering through perforations of an appropriate shade, and reflected by the inclined mirrors, act simultaneously on opposite sides of the bulb. The mean result of repeated trials, all differing but slightly, show that the energy of the direct solar rays acting on the polygonal reflector is reduced 0.235 before reaching the heater.

In accordance with the previous article, the investigation has been based on the assumption that, *the temperatures produced by radiant heat at given distances from its source are inversely as the diffusion of the rays at those distances. In other words, the temperature produced by solar radiation is as the density of the rays.*

It will be remembered that Sir Isaac Newton, in estimating the temperature to which the comet of 1680 was subjected when nearest to the sun, based his calculations on the result of his practical observations that the maximum temperature produced by solar radiation was one-third of that of boiling water. Modern research shows that the observer of 1680 underrated solar intensity only 5° for the latitude of London. The distance of the comet from the center of the sun being to the distance of the earth from the same as 6 to 1000, the author of the "Principia" asserted that the density of the rays was as $1000^2$ to $6^2$= 28,000 to 1; hence the comet was subjected to a temperature of $28{,}000 \times \frac{180°}{3}$ =1,680,000°, an intensity exactly "2,000 times greater than that of red-hot iron" at a temperature of 840°. The distance of the comet from the solar surface being equal to one-third of the sun's radius, it will be seen that, in accordance with the Newtonian doctrine, the temperature to which it was subjected indicated a solar intensity of $\frac{4^2 \times 1{,}680{,}000}{3^2}$=2,986,000° F.

The writer has established the correctness of the assumption that "the temperature is as the density of the rays," by showing practically that the *diminution* of solar temperature (for corresponding zenith distances) when the earth is in aphelion corresponds with the increased diffusion of the rays consequent on increased distance from the sun. This practical demonstration, however, has been questioned on the insufficient ground that "the eccentricity of the earth's orbit is too small and the temperature produced by solar radiation too low" to furnish a safe basis for computations of solar temperature.

In order to meet the objection that the diffusion of the rays in aphelion do not differ sufficiently, the solar pyrometer has been so arranged that the density, *i. e.*, the diffusion of the reflected rays, can be changed from a ratio of 1 in 5,040, to that of 1 in 10,241. This has been effected by employing heaters respectively 10 inches and 20 inches in diameter. With reference to the "low" solar temperature pointed out, it will be perceived that the adopted expedient of increasing the density of the rays without raising the temperature by *converging* radiation, removes the objection urged.

Agreeably to the dimensions already specified, the area of the 10-inch heater acted upon by the reflected solar rays is 331.65 square inches, the area of the 20-inch heater being 673.9 square inches. The section of the annular sunbeam whose direct rays act upon the polygonal reflector is 3,130 square inches, as before stated.

Regarding the diffusion of the solar rays during the investigation, the following demonstration will be readily understood. The area of a sphere whose radius is equal to the earth's distance from the sun in aphelion being to the sun's area as $218.1^2$ to 1, while the reflector of

the solar pyrometer intercepts a sunbeam of 3,130 square inches section, it follows that the reflector will receive the radiant heat developed by $\frac{3,130}{218.1^2}=0.0658$ square inch of the solar surface. Hence, as the 10-inch heater presents an area of 331.65 square inches, we establish the fact that the reflected solar rays, acting on the same, are *diffused* in the ratio of 331.65 to 0.0658, or $\frac{331.65}{0.0658}=5,040$ to 1; the diffusion of the rays acting on the 20-inch heater being as 673.9 to 0.0658, or $\frac{673.9}{0.0658}=10,241$ to 1.

The atmospheric conditions having proved unfavorable during the investigation, maximum solar temperature was not recorded. Accordingly, the heaters of the solar pyrometer did not reach maximum temperature, the highest indication by the thermometer of the small heater being 336°.5, that of the large one being 200°.5 above the surrounding air. No compensation will, however, be introduced on account of deficient solar heat, the intention being to base the computation of solar temperature solely on the result of observations conducted at New York during the summer solstice of 1884. It will be noticed that the temperature of the large heater is proportionally higher than that of the small heater, a fact showing that the latter, owing to its higher temperature, loses more heat by radiation and convection than the former. Besides, the rate of cooling of heated bodies increases more rapidly than the augmentation of temperature.

The loss occasioned by the imperfect reflection of the mirrors, as before stated, is 0.235 of the energy transmitted by the direct solar rays acting on the polygonal reflector, hence the temperature which the solar rays are capable of imparting to the large heater will be $200.5°\times1.235=247.617°$; but the energy of the solar rays acting on the *reflector* is reduced 0.207 by atmospheric absorption, consequently the ultimate temperature which the sun's radiant energy is capable of imparting to the heater is $1.207\times247.617°=298.87°$ F. It is hardly necessary to observe that this temperature (developed by solar radiation diffused fully ten-thousandfold) must be regarded as an *actual* temperature, since a perfectly transparent atmosphere, and a reflector capable of transmitting the whole energy of the sun's rays to the heater, would produce the same.

The result of the experimental investigation carried out during the summer solstice of 1884 may be thus briefly stated. The diffusion of the solar rays acting on the 20-inch heater being in the ratio of 1 to 10,241, the temperature of the solar surface cannot be less than $298.87°\times10,241=3,060,727°$ F. This underrated computation must be accepted unless it can be shown that the temperature produced by radiant heat is not inversely as the diffusion of the rays. Physicists who question the existence of such high solar temperature should bear in mind that in consequence of the great attraction of the solar mass, hydrogen on the sun's surface raised to a temperature of 4,000° C., will be nearly twice as heavy as hydrogen on the surface of the earth at ordinary atmospheric temperatures; and that, owing to the immense depth of the solar atmosphere, its density would be so enormous at the stated low temperature that the observed rapid movements within the solar envelope could not possibly take place. It scarcely needs demonstration to prove that extreme tenuity can alone account for the extraordinary velocities recorded by observers of solar phenomena. But *extreme tenuity* is incompatible with low temperature and the pressure produced by an atmospheric column probably exceeding 50,000 miles in height subjected to the sun's powerful attraction, diminished only one-fourth at the stated elevation. These facts warrant the conclusion that the high temperature established by our investigation is requisite to prevent undue density of the solar atmosphere.

It is not intended at present to discuss the necessity of tenuity with reference to the functions of the sun as a radiator; yet it will be proper to observe that on merely dynamical grounds the enormous density of the solar envelope which would result from low temperature, presents an unanswerable objection to the assumption of Pouillet, Vicaire Sainte-Claire Deville, and other eminent *savants*, that the temperature of the solar surface does not reach 3,000° C.

# ON THE MECHANICAL EXAMINATION AND TESTING OF PORTLAND CEMENT.

By HENRY FAIJA, Assoc. M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

It may be assumed that the object of testing cement is to ascertain its value for constructive purposes, and it is the aim of the author to examine the tests to which cement is generally subjected, and to see how far they attain their object.

The requirements of any test or combination of tests are, that the conclusion shall be absolute, and that the time occupied in arriving at that conclusion shall be as short as possible; and further, as all opinions formed by the examination of a cement must be based on the results of previous examinations and tests, it is evidently of importance that a uniform means of testing should be adopted, so that users and manufacturers may be able to compare their own tests with those by other people. At present the tests made by one person are of little use to anyone else, owing to differences of manipulation and detail.

The ordinary practice is to find the value of a cement by making it into briquettes and ascertaining their tensile strength when seven days old, as well as by its fineness, weight, and color; from the results obtained and their relative bearing to each other, a correct opinion is presumably arrived at.

Mr. Mann lately presented to the Institution the results of some experiments on the adhesion of cement to different materials, and by this means ascertained its value for constructive purposes. Nor must it be forgotten that Mr. Grant has introduced the sand test into this country from Germany, which is another test for adhesion; for although the briquettes made of cement and sand are tested for tensile strength, it is the adhesion between the sand and the cement which gives the briquette its tensile strength. Whether either of these enables a more definite conclusion to be arrived at than the ordinary method, the author does not venture to offer an opinion. He thinks, however, that neither of them is likely to supersede the generally accepted requirements of a test, and that therefore they are detrimental to the interests of uniform testing.

The author in this paper first considers the details of manipulation and other matters affecting the results obtained in a cement test, and afterwards the properties which a good cement should show in each detail.

In testing cement for tensile strength several points materially affect the result; namely, the percentage of water used in gauging. The skill of the manipulator, which practically means the time occupied in reducing the cement to a proper consistency, and the dexterity in filling the moulds, so that a sound briquette free from air bubbles may be obtained with the minimum of water in the minimum of time. The form and construction of the mould in which to form the briquette. The careful removal of the briquette from the mould and its subsequent handling. The time which elapses between the formation of the briquette and placing it in water. And the manner and speed at which the weight is put on the briquette when being tested.

It may be assumed that, as far as the tensile strength is concerned, a better result than can possibly be secured in practice should be obtained in the testing room; but it is of greater importance that a uniform result should be obtained by all persons engaged in testing cement, and that a uniform procedure should be adopted, than that the acme of perfection should be attained. The skill of the operator having a great deal to do with the result, it is necessary to reduce the operation of gauging the cement to, as nearly as possible, a purely mechanical process. This can be accomplished by a gauging machine devised by the author. It gives in ordinary hands as good a result as the most expert operator obtains when gauging in the usual way with the trowel. By employing the gauger the cement is

brought to a proper consistency to be put into the moulds in considerably less time; and by reducing the labor and wrist work necessary to properly gauge a cement, the inducement to slovenly manipulation and the use of more water than is necessary is obviated.

The advantage gained by adding the minimum of water for gauging has for sometime been acknowledged, and the results of experiments by Mr. Grant and others, and by the author, which have from time to time been published in the Proceedings of this and other Institutions, are sufficient to show that such is the fact. It is impossible to name a fixed quantity, as hardly any two cements require the same, and it can only be determined by making experimental pats previous to proceeding with the test. The maximum amount of water may, however, be fixed at 18 per cent.

That the time occupied in gauging a sample of cement effects the result obtained is hardly a matter to prove by experiment, it being evident that if cement is worked after it has commenced to set, its nature must be altered, and the result cannot be reliable; this, though it applies in a more marked degree to quick-setting cements, it is true of all.

The form of briquette must materially affect the result in testing for tensile strength. The author can only say that the form brought forward three years ago by Mr. Grant in a paper before this Institution, gives undoubtedly the best results, and he should like to see that form universally adopted. It is hardly necessary to add that the moulds should be of metal; resting on glass, metal or other non-porous bed. If a porous or partially porous bed is used, an excess of water in gauging is quickly withdrawn from the briquette, and the setting being thus accelerated, a better result is shown at short dates, though eventually there would probably be no difference. But inasmuch as a test of cement for practical purposes never exceeds twenty-eight days, and is generally confined to seven, a misleading result is obtained if this detail be not attended to.

The next item of importance is the time allowed to elapse between the gauging of the cement and placing the briquette in water. Experiments prove that the greatest tensile strength is obtained when the briquette is put in water directly it is set. With quick-setting cements this may be in an hour or two after gauging, and with slow-setting cements it may be extended to ten, fourteen, or twenty hours. The danger, however, is, that if this practice be adopted, in unskillful hands the briquette may be put in water a little to soon, when the cement would be acted upon detrimentally. It is therefore advisable that a given number of hours should be determined upon, and this by practice has been fixed at twenty-four hours.

In testing all other materials the rate of speed at which the weight or strain is applied is considered, but it seems to have been persistently ignored when testing cement. Its importance, however, must be as great with one material as with another. Mr. W. Matthews, M. Inst. C.E., and Mr. P. Adie, Assoc. Inst. C.E., have devised an automatic arrangement for running the weight along a steelyard, and it is fixed to most of Mr. Adie's testing machines. It ensures the weight being put on to the briquette at an even and regular speed, though no special speed seems to have been adopted. The principle on which it works is that of a falling weight governed by a water-brake. Dr. Michaelis' machine, in which the weight is applied by allowing shot to fall into a pan at the end of a compound lever, as well as Bailey's machine, in which water is used instead of shot, might both be easily arranged to apply the weight at a standard speed.

Notwithstanding the different results which it is evident would be obtained through variation in the speed of applying the weight, the author is not aware of any exhaustive experiments having been made, or any conclusion arrived at on the subject; he has therefore recorded the details of an experiment comprising over six hundred briquettes. The briquettes were broken at five different speeds, varying from 100 lbs. in one second to 100 lbs. in two minutes; these being considered the limits which it was possible to adopt in practice. By taking the average percentage of difference he has been enabled to draw a curve, showing the different results to be expected from applying the weight at different speeds. Though an experiment comprising only six hundred examples cannot

perhaps be considered conclusive, yet it enables a fairly good average to be obtained, especially as several different cements were used throughout the experiment. Although in each series the same cement was used, the gauging was all done at one time, and in exactly the same manner, by the same man.

The results were as follow:

| | |
|---|---|
| Increase per cent. between 100 lbs. in 1 min. and 100 lbs. in 2 mins., | 3.960 |
| Increase per cent. between 100 lbs. in 30 secs. and 100 lbs. in 1 min., | 3.528 |
| Increase per cent. between 100 lbs. in 15 secs. and 100 lbs. in 30 secs., | 4.028 |
| Increase per cent. between 100 lbs. in 1 sec. and 100 lbs. in 15 secs., | 10.726 |
| Total per cent. between 100 lbs. in 2 mins. and 100 lbs. in 1 sec., | 23.142 |

The great difference shown by this experiment must impress every user and manufacturer of cement with the importance of adopting a standard speed at which the weight is to be applied; and it seems that the most convenient would be either the 100 lbs. in fifteen seconds, which the author uses in his testing room, or a little slower, but certainly not slower than 100 lbs. in thirty seconds, on account of the length of time which a test would occupy.

The author is of opinion that by adopting the before-mentioned or similar means and appliances for gauging the cement and priming the briquettes, the results obtained by different experimenters would approach more nearly to each other, a better estimation of the value of a cement would be possible, and a comparison would be more easily and more definitely decided.

The determination of the fineness of a cement can of necessity only be carried out in one manner, and is not subject to error. The weight per striked bushel, however, is open to considerable argument. The manner in which the measure is filled is of necessity all-important, it being assumed that the cement is to be put into the measure as lightly as possible.

As an alternative test or in conjunction with the foregoing, the specific gravity of a cement may be ascertained, with this advantage, that while the weight per bushel varies with the fineness to which the cement is ground, the specific gravity is of necessity constant.

The usual method of determining whether or not a cement will blow, is by making a few small pats and placing them in water as soon as they are set, which may be in one hour or two or more hours, according to whether the cement is quick or slow-setting, and by examining them daily to see if they develop cracks or otherwise alter in form. That the inference drawn from the result thus obtained is a true one, is extremely doubtful; and the author has thefore adopted another method to determine what, in his opinion, is the most dangerous property that a cement can possess.

Some years ago the author made numerous experiments with the view of accelerating the setting or hardening of cement and concrete, which resulted in his taking out a patent for that purpose. The process is only referred to because out of it has come a little apparatus of great value in the testing room, which enables a decided opinion to be formed within twenty-four hours as to whether the cement under examination will blow, or if it is a safe cement to use. The principle of the author's process for hardening is to subject the concrete immediately on gauging to a moist heat of about 90° Fahrenheit, and afterwards to keep it in a warm silicious bath at a temperature of about 100°. It was found that if by accident these temperatures were materially increased, the concrete sometimes gave all the appearance of having been made with a blowy cement. From this it was opined that a good cement would not blow at these temperatures, and further experiments have proved such to be the case, and also that a cement which does not stand this treatment is improperly made and will sooner or later blow. The author therefore devised an apparatus. It is a moist heat chamber and bath conbined in a small space; but the bath is only water instead of silicious. The mode of using it is to make a small pat of the cement under examination on a piece of glass and immediately to place it into the moist heat part of the apparatus. When it is set, which, even in the case of very slow-setting cements, will be within two or three hours, it is taken out of the moist heat chamber and placed in the bath. If next morning the pat is perfectly sound, it is decided that the cement will not blow; if, on the other hand, it is swollen and

blown, then the cement is considered unfit for use. It would not, however, be fair to say that because under these conditions the pat was blown, it is an improperly made cement, for the blowing might be due to extreme freshness,

Under these circumstances, therefore, it is necessary to put a small quantity of cement on a tray in a thin layer, and to let it thoroughly cool for two or three days. If a pat made from this cooled cement blows when submitted to the influence of the moist heat and warm bath, the author would on no account advise the use of the cement. On the other hand, if it does not blow, it is pretty clearly shown that the cement is sound but too fresh, and that the bulk should be turned over three or four times and cooled before use.

The author proposes in the second portion of the paper to consider the properties which a good and useful cement should develop when being tested, under three divisions; firstly, those properties which have already been amply experimented upon, and which may be considered as proved and acknowledged; secondly, those which may be termed the problematical, which though inherent to a good cement may also be found in a bad one; and thirdly, the absolute strength and behavior of the cement at different dates.

Of the first, it may be considered that both users and manufacturers are cognizant of the importance of a cement being finely ground, and that, given a certain cement, the best result is obtained when it is finely ground. There is, however, a limit which commercially cannot be exceeded, except of course at an increased price, or until other machinery has been invented for grinding. This limit seems to be that the cement shall all pass through a sieve having 900 meshes to the square inch, and shall not leave more than 10 per cent. residue on a sieve having 2,500 meshes to the square inch. This degree of fineness is for all practical purposes sufficient; and if a user thinks he can obtain a better result by having a finer ground cement, he should be prepared to pay a higher price for it.

The weight per striked bushel specific gravity or density of a cement, are in the highest degree problematical tests. It is assumed that a heavy cement means one with a proper quantity of lime in its composition and well calcined, and a light cement the reverse; but it does not of necessity follow that such is the case. It is also possible to have a cement too heavy, and, as pointed out by the author ten years ago, and by others since, the weight must bear a definite relation to the fineness. Of necessity the finer the cement, the lighter it will weigh. It is generally considered that a cement of the fineness previously specified should weigh from 110 to 114 lbs. per striked bushel, when the bushel measure is filled in a manner similar to that adopted by the author. The specific gravity corresponding to this weight and fineness is from 3.00 to 3.08.

The color of a cement is almost too problematical to deserve consideration, except when examining cements made from similar materials, as the varying properties of different raw materials must of necessity affect the color. But the author puts very little value on these problematical tests as a means of assisting in the determination of the value of a cement.

The absolute behavior of the cement when made into briquettes and tested at different dates, and the careful examination of its behavior during gauging and setting, are the best means for determining its value for constructive purposes.

The determination of what the tensile strength of a cement should be at certain dates, is the one point on which all authorities seem to differ, and yet it is the one test which has been experimented upon more than all other tests put together. If, however, all the experiments which have been published are examined, it does not seem difficult to arrive at a just conclusion. The author has made thousands of tests in this direction; he has examined all the tests which have been published in England, and some of those from Germany, and the result of these tests and examinations is, that good cement, which practically continues to increase in strength for a period over which it is possible to make a test, has a tensile strength, when tested in the ordinary manner, of not more than 300 lbs. or 350 lbs. per square inch at the expiration of seven days from gauging; while the same examination shows that many of those cements which at the same age carry 400

lbs. or 500 lbs. actually deteriorate before they are a year old.

The author is of the opinion that the strength at a single date does not define with sufficient accuracy the value of a cement; but that two dates should be determined upon, and the increase per cent. in strength between those dates will better define the nature of the cement than the actual strength at either. As an example, the two following cements may be cited:—

| — | 3 Days. | 7 Days. | 28 Days. | 3 Months. |
|---|---|---|---|---|
| No. 1..... | 390 | 460 | 520 | 510 |
| No. 2..... | 205 | 375 | 490 | 590 |

Consider the behavior of No. 1 cement up to twenty-eight days. It is superior in every way to No. 2; though the increase of strength between each date is but little, while No. 2 increased 85 per cent. between the three and seven days, and 30 per cent. between the seven and twenty-eight days. The latter therefore appears, as indeed is proved by the result of a three-months' test, to be still increasing in strength, and likely to do so for some time, while No. 1 is a cement which develops all its strength in a short period. It is therefore not likely to increase in strength with age, and may possibly deteriorate. It would not, however, satisfy the case to define only the increase per cent. which should take place between certain dates; but a minimum and maximum strength should be determined upon at the earlier date, as indicative of a good cement, and a specified increase above that for all future tests named. In the author's opinion, the tensile-strength of a briquette three days old should be at least 175 lbs., and should not exceed 275 lbs. per square inch; the increase of strength between the three days and seven days should be from 40 to 50 per cent.; and if a twenty-eight days' test is adopted, the increase should be from 20 to 30 per cent. of the strength shown at the seven days.

A slow-setting cement does not practically increase in temperature during setting; it is only the quick-setting ones which develop this characteristic. Many quick-setting cements when fresh will increase in temperature as much as 16° and 18° Fahrenheit in eight or ten minutes from gauging, and will not return to their normal temperature for more than an hour. If cement possessing this characteristic be cooled, it will be slower setting, and the increase in temperature during setting will not be so great. This test may therefore be often useful in assisting in the immediate determination of the value of a cement.

The author maintains that there should be a uniform standard specification, compliance with which would ensure a thoroughly good and sound cement, which manufacturers would be able and willing to supply at the ordinary market prices. A standard specification has been for many years adopted in Germany and other countries, and has proved of great benefit to the industry, and there is no reason why it should not be equally beneficial in this country. Shippers, and users who require only a few hundred tons at a time (and it must not be forgotten that these take up the bulk of the cement made in this country), know that they were obtaining a good and useful article. Such an arrangement would in no way interfere with engineers, or others who use large quantities, adopting their own specification, and there is no doubt manufacturers would be prepared to comply with their demands under special conditions. In order, however, to ensure success, a standard specification should be one which, while meeting all requirements, should be simple and conclusive, and at the same time expeditious. In nine specifications out of ten, many of the items demanded are contradictory, and many often useless. It therefore seems necessary to examine the clauses usually inserted in a specification, and see what assistance they render in determining the value of the cement, so that the actual clauses in a specification may be reduced to a minimum. Taking them in order, they generally appear to be: first, the weight; second, the fineness; third, the examination of pats; fourth, the color; fifth the tensile strength at seven days; sixth, that the cement shall set in a certain time.

Notwithstanding that this hitherto has been considered a good and efficient test, the author believes no correct estimate of the value of the cement can be arrived at by the comparison of the results ob-

tained, and therefore would substitute for them the following :—

First, fineness; second, absence of blowing, determined by the use of the apparatus already described; third, the tensile strength at three and seven days, and the increase per cent. between those dates. In addition, a twenty-eight days' test might be adopted if practicable; but in many cases—certainly in all cases of shipment—it is impossible to allow the examination of the cement to extend over such a long period.

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## TEMPERATURE OF THE SUN.

By DeVOLSON WOOD, M. A., C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THIS most important point in Mr. F. Gilman's criticism, in the last September number of this magazine, of my article in the last July number, is whether the law of the inverse squares as applied to heat is applicable to extended surfaces. If his assertions be taken in place of proof, little need be said; but on this point there is a show of reasoning, inasmuch as he asserts that "gravitation, light and radiant heat conform to the same law." In examining the truth of this assertion, we begin with the fundamental principle of the attraction of matter—that the attractive force between any two particles varies directly as the products of their masses and inversely as the square of the distance between them; thus expressed $\frac{mm'}{r^2}$. The law has no existence in reference to a single material particle only, as Gilman seems to imply. Do light and radiant heat necessitate two bodies, one to impart and the other to receive? But the law especially referred to is that of the inverse squares. Can it be said of gravity that the force varies inversely as the square of the distance unless there be an external body, so that there may be mutual action between them? Is it necessary to have an external object in order that the intensity of heat shall vary inversely as the square of the distance? (Admitting the law, for the moment). In the case of gravitation, is not the attractive pull (so to speak) the same on both bodies, regardless of their relative size? And is this the same with light and heat? The answers to these questions are evident, and are only made to show fundamental differences.

Mr. Gilman says: "But it has been proved that the same law of gravitation prevails in a spherical homogeneous mass of any dimension, when the distance is measured from the center"—a statement partly true and partly false. He here confines his attention to *one* body, and in that sense it is not correct. In the next place, assuming that he would have the action of the sphere upon a particle, it is not true if the particle be within the sphere, for in that case it is found that the attraction upon the particle at the center of the sphere is zero, and increases as the distance from the center to the surface. Is this true of a hot sphere? Is it true that there is no heat at the center of such a sphere? And does the heat increase from the center outward? Answers are unnecessary. But for fear that it may be said that this is not a fair case, it will be well to observe that this law of increase of gravity in the homogeneous sphere is deduced from the fundamental law of gravity between particles.

But it may be properly claimed to be true for the attraction of a homogeneous sphere upon an external particle—or, to be more precise, for the attraction *between* such a sphere and an external particle. But it must be observed that this "has been proved" by means of the law relating to the attraction *between particles*; and in this proof it is assumed that the attraction between the external particle and the most remote one of the sphere is precisely the same as if they were the only particles considered. In other words, the attraction is the same whether bodies intervene or not. Has it been proved that the same law holds for

radiant heat in this case? The above result may be thus stated: The attraction between two homogeneous spheres is the same as if their entire masses were concentrated at their respective centers. Can a similar statement be made of radiant heat? If so, where is the proof? Further, by means of the fundamental principle above stated, the principle holds for gravity when the spheres are not homogeneous, provided only that each of the concentric spherical shells of which the spheres may be conceived as composed, are of the same density, but varying from one to the other in any manner. When Prof. Tait is correctly reported, it will be found that he does not support the theory that the law of the inverse squares "is also applicable in the case of heat radiating from a spherical body, such as the sun." We do not understand how Mr. Gilman can insist upon this law of the inverse squares in this case and at the same time admit that the law of Petit and Dulong is reliable even to nearly 400° F., since the latter is entirely at variance with the former. I suppose that both of us have typographical errors in the notation of the formula

$$Q=1.146fa^t .$$

In my article it should have read $a=1.0077$, and Q should be substituted for $r$, and with these corrections the formula was sufficiently correct for my purpose, though not exact; but if the formula quoted by Mr. Gilman gives better results, or results more favorable to Captain Ericsson's theory, we are willing he should profit by it. It is safer to extend an approximate empirical formula beyond the limits of strict applicability, than to use a principle not founded on reason or experiment. We made no claim for accuracy of the result, but simply showed that, according to recognized theories, the temperature of the sun might be about 5000° Fahr.

But Mr. Gilman asserts that the law of the inverse squares "gives the temperature of the medium in the vicinity of the body" and "Capt. Ericsson has proved the temperature of the medium in the vicinity of the sun is at least 1,303,640° Fahr." What medium is here referred to? Is it the luminiferous ether? If so, who can say that it is not diathermanous? Or is some other medium referred to? The assertion is a bold one.

Finally, let Mr. Gilman extend his calculation, by assuming that the body is 400,000, 100,000, &c. miles from the center of the sun and determine its temperature!

## GERMAN REGULATIONS AS TO THE CONSTRUCTION OF IRON BRIDGES.

From "The Engineer."

At a meeting of the German Association of Architects and Engineers held in October, 1881, the question of normal regulations for the delivery of iron structures for bridges and buildings was discussed. The subject was then referred to the Saxony Association, for the drawing up of a series of regulations on the subject. The matter has since that time been under consideration, and during last autumn the work projected was accomplished.

In the scheme drawn up—signed by Messrs. Centner, Ehrhardt, Frankel, and Fritzche—the question of bridge construction has been treated in a comprehensive manner; less attention having apparently been given to that portion of the subject which refers to building work. The following is a summary of the principal features of the scheme in question, given in detail by the *Wochenblatt fur Architekten und Ingenieure.*

*I. Technical basis of construction:* (A) *Intrinsic weight of the structure;* (B) *Alterable vertical load.*—(*a*) In railway bridges this is represented by a train consisting of three of the heaviest locomotives in prospective use, and an unlimited number of loaded goods trucks. (*b*) The traffic on road bridges consists of foot passengers and carriages. For

main girders of bridges, of about 65½ ft. span, concentrated loads upon one or two axles are more unfavorable than the burden of a crowd, but in the larger bridges the latter is the most unfavorable. This last-named pressure can as a rule be estimated at about 82 lbs. per square foot, but in cases of a compact crowd the pressure may be as high as 114 lbs. per square foot. The prospective burden of carriages has to be estimated according to the probable character of the vehicles and the description of roadway; the portion of the roadway not covered with vehicles being supposed to be filled with a crowd. In some cases regard must be paid to a probable load of street locomotives. (*c*) In buildings the movable burden of the floors, burden of snow on the roof and wind pressure. (C) *Horizontal forces.*—(*a*) The wind pressure acting horizontally may be estimated for the loaded bridge at 30¾ lbs. per square foot, and for the unloaded bridge at 51¼ lbs. per square foot, or, in a specially exposed situation, even at 57¼ lbs. per square foot. (*b*) In curved railway bridges the effect of the centrifugal force for the maximum speed of the trains has to be taken into consideration. (D) *Allowable requirements of the material used in the construction.*—The employment of the formulas founded on Wöhler's tests is suggested, but the following strengths are mentioned as maximum requirements: Welded iron, 7,625 tons per square inch; steel, 11.5 tons per square inch. Wide flanged welded iron I girders—where the width of the flanges exceeds that of the German normal profile—even if they have only to support a fixed load, should not be required to stand a test of above 5 tons per square inch in tension. In calculations affecting rivets there should not be more strength claimed than about 3.75 tons per square inch of rivet section. Cast iron should be required to stand tests for extension of 1.625 tons per square inch, and for pressure of 4.75 tons per square inch.

*II. Preparations of contract drawings and calculations.—III. The preparation of working drawings.*—The drawings and calculations on which a contract is based are, as a rule, prepared by the building authorities, and when the adjudication takes place the contractor receives attested copies. If these are—apart from the general plan—on the scale of one-twenty-fifth to one-twentieth of the natural size for entire main girders, and one-tenth the natural size for the details, no further working drawings are required. Any defects arising in the work are not to be excused on the ground of want of clearness or imperfections in the drawings. Any changes suggested by the contractor are to be notified within a given period. When special working drawings are to be prepared by the contractor, they are to be submitted in duplicate to the building authorities within a given time after the adjudication. Any purchases of materials or other steps taken before the approval of these working drawings are at the contractor's risk. The calculations as to weight are in most cases prepared by the authorities and annexed to the contract. If they are in accordance with the dimensions shown in the drawings no further calculations of weight are required, but the contractor is bound to examine them. Should approximate weights only have been given, the contractor is bound to send in within a given time in duplicate an exact calculation of weights. The following standards of weight are to be taken as a basis:—Cast iron, 452⅜ lbs. per cubic foot; wrought iron, 486¼ lbs. per cubic foot; steel and ingot iron, 490⅝ lbs. per cubic foot.

*IV. Selection, quality, and testing of the materials.*—(*a*) The bearing portions of the structure, such as the main girders, cross girders, and intermediate girders, as well as all portions which are liable to deflection, are in general to be made of wrought iron. It is recommended in bridge building to use wrought iron instead of cast iron columns. As to the use of mild steels, caution is advised in the present conditions of methods of manufacture. (*b*) The definition of the quality of the material of the construction must be governed by its working capabilities. (*c*) The wrought iron used must at least possess the qualities specified in the conditions of classification issued in May, 1881, by the Association of German Ironworks. As to mild steel and ingot iron, tests can hardly be specified on account of the insufficiency of experience relating to them. The cast iron portions must be cleanly made of grey soft iron in the prescribed dimensions. They must

contain neither blisters, holes, fissures, nor any other defects. The minimum strength must be—against tension 7 tons per square inch; compression 38 tons per square inch. Cast iron columns and supports are tested up to double the burden for which they are constructed. The minimum thickness of metal for cast iron columns is $\frac{2}{5}$ inch.

*V. Cleaning and painting.*—Previous to the separate parts being put together —plates, bars, &c.—the rust and hammer slag are to be removed from the iron. The mode of cleaning is left to the contractor's option, but he must give notice of what it is, and is responsible in the instance of chemical cleaning for any subsequent rusting arising from want of care in the removal of the acids used. The cleaned portions are to be coated with a varnish of boiling hot linseed oil, which must be thin and quick in drying. Until dried, the portions thus coated must be properly sheltered. The building authorities are at liberty to arrange for a provisional acceptance when the riveting is completed, after which the grounding of the parts may be effected with a protecting ground paint. For this purpose a varnish of linseed oil with red lead is recommended, but the operation must not take place during damp weather in the open air. This provisional acceptance is not any agreement on the part of the building authorities as to the correctness of the measurements or the number of pieces in the construction. The larger portions are only to be grounded on the building site after revision. After the iron portions are in position, all the joints are to be carefully filled up, at the surfaces of contact, with a putty composed of white lead and linseed oil varnish, and a grounding of red lead is to be applied to the heads of the rivets driven in on the building site. Besides, all spaces between portions of the construction where water might accumulate have to be carefully filled up with asphalt. The entire construction subsequently receives from the building authorities a second coat of oil paint. Should the zincing—galvanizing—of any portions be prescribed, it should be effected by a strictly uniform coating. The portions thus treated should be capable of being bent until they break without the zincing, *i.e.*, what is incorrectly called galvanizing in this country, becoming detached. The coating of zinc must be as free as possible from lead.

*VI. The manufacture and putting together of the separate parts.*—All the parts of the construction must exactly correspond with the drawings and fulfill the following conditions:—(*a*) The portions fastened with rivets or screws must fit closely together. (*b*) All iron portions must be rolled or forged out of one piece of iron, and not be formed by the welding together of separate pieces. Any exceptions have to be specified. (*c*) Angles and bending are to be avoided as far as possible. (*d*) The rivet holes must correspond as to diameter and position with the drawings. The holes which are drilled at the building site should be about $\frac{1}{25}$ of an inch narrower than the diameter of the rivet requires, so that a good fit is insured after its being enlarged. (*e*) All screw holes and rivet holes are to be carefully drilled. (*f*) Where several holes meet each other in the parts to be united, a horizontal dislocation of not more than 5 per cent. of the diameter of the hole is allowable. The holes must, however, be made perfectly equal with the rimer, and not by filing on one side. Rivet bolts of proportionately large size must be used in holes thus enlarged. (*g*) The rivets are to be inserted at a bright-red heat—after being carefully freed from scales—into the duly cleared rivet holes in such a manner that they are quite firm after the head is completed. (*h*) After the riveting, it is to be tested whether the rivets are quite firm. All that are not firm or do not correspond with the above-named conditions are to be removed and replaced by others. No further driving is under any circumstances to be permitted in the cold state. In the putting together of the parts, care is to be taken that none of them is forced into a one-sided tension. Should any portions become distorted in the riveting, the connections must be loosed and the faults carefully remedied.

*VII. Extent of completion in the workshops.*—In all parts not to be riveted in the factory, provisional screw bolts must be inserted. Riveting upon the building site is to be confined to the smallest possible extent, and, therefore, the completion of all possible parts of the work at the factory is recommended.

*VIII. Suspension of the execution and acceptance of the work in the workshop.*—The building authorities have the right of constant or occasional skilled supervision of work in the workshops, and the necessary appliances and force for tests and examinations must be furnished to them, or obtained by them at the contractor's expense. All portions not according to the prescribed regulations, or otherwise unserviceable, are to be marked in such a manner that their subsequent employment in the structure may be recognized. The examination of the iron material and the control of the execution in the workshop does not prevent the rejection of the work delivered, during or after the erection of the structure, if defects show themselves.

*IX. The mode of ascertaining the weight.*—For the purpose of computation all parts of the structure should, if possible, be weighed, but when this is impracticable, a certain number of objects selected by the building committee should be officially weighed for the purpose of obtaining reliable indications regarding the total weight of the structure. The computation then takes place according to the agreed prices on the basis of the total weight as ascertained, if the latter does not exceed the original computed weight by more than 3 per cent. If the excess of weight is more than 3 per cent., the contractor is only paid for 3 per cent. extra. Any shortness in weight is deducted. Portions of a structure which are more than 5 per cent. above the estimated weight, or more than 2 per cent. under it, can be at once rejected.

*X. The stonework of bridges.*—The bed stones are delivered to the contractor in the correct position of altitude, and the middle line of the bridge construction is marked on the pillars in a distinct manner. The contractor is supposed to ascertain by his own measurements, before the erection begins, the exact dimensions, and to control the same according to the drawings, reporting any differences to the building authorities, and awaiting their decision; otherwise the contractor is liable for any ultimate difficulties. The contractor is specially bound to carry out the correct and exact placing in position of the main girders. The masons' and stone-dressers' work in connection with the final works is looked after by the building authorities, who likewise provide the necessary materials.

*XI. The erection on the site.*—The methods to be employed in the erection of the ironwork and of the scaffolding are generally left to the judgment of the contractor, but the building authorities have the right in letting out the contract to stipulate for a certain mode of erection. The machinery for hoisting and other appliances have to be supplied by the contractor at his own expense. As the erection of scaffolding, &c., is subject to local regulations, the building authorities are to give the contractor, in the conditions for delivery, all available information, plans, &c., bearing on this point, as also upon the question of land and water transport for materials, &c. Plans of the scaffolding—scale 1:100—are to be submitted within a given time after the adjudication—by the building authorities to the local officials for examination and approval. Those parts of the masonry on which the bed-plates are to be placed should be put at the disposal of the contractor a given time before the date fixed for the completion of the ironwork. Should the masonry not be ready, the contractor must be apprised of the altered circumstances, but any compensation under this head must be a stipulation of the contract. The officials charged with the supervision of the erection are authorized to satisfy themselves in any way they wish as to the quality of binding materials not yet tested. A repetition of tests for strength already carried out in the workshops can only be ordered by the building authorities in special cases. The contractor is bound to follow the instructions of these officials within three days, but has the right of appeal to the building committee. In urgent cases the officials have the right to order the suspension of the work, but if it is found on appeal to the building authorities that such a course was not justified, the contractor is entitled to compensation for any injury he has sustained, and the period of suspension is added to the time originally fixed for the execution of the work.

*XII. The testing and acceptance of the completed work: (a) super-elevation of girders.*—Truss and lattice girders, &c., are laid with a camber, which is computed upon the principle that after the

work is finished and the load has produced its natural effect, there should remain a camber equaling half the bending which would have been produced by a similar moving load.

(*b*) *Tests for load.*—These vary according to the purposes of the structure. Railway bridges are tested by a train being placed on each of the lines. This train consists of three of the heaviest goods engines available, the first with the chimney in front and the two others with the chimneys in opposite direction to each other, and loaded goods trucks of the heaviest description in use upon the railway in question. These trains are placed upon that portion of the bridge which corresponds with the greatest momentum, and the amount of deflection after six hours is measured in the center of the main girders and at the main piers. The train is then removed and the amount of permanent deflection of the girders is ascertained. Finally the bridge is crossed at the maximum speed allowed upon the line, and the amount of transitory and permanent deflection is ascertained. For testing road bridges a testing weight is brought upon the roadway and the footpaths, where it is left for twenty-four hours. A row of the heaviest loaded vehicles which have been provided for in the construction of the bridge is driven step by step over it, and is then allowed to rest half an hour upon it. In both cases the transitory and permanent deflection of the main girders is ascertained, as previously explained. The marching of men in time, as well as the rapid driving of vehicles over the bridge, are not excluded, but must be provided for in the conditions for the construction. The most unfavorable combination of the burdens of the separate openings is produced with continuous girders. A small permanent deflection after the removal of the first trial load cannot be attributed to any defect in the construction if no permanent deformation of the separate parts of the work can be proved. Further trials should, however, not produce any further deflection. The measured elastic deflection with fixed and moving loads must not in any case exceed the computation by 15 per cent. Any differences in temperature which may have intervened should be regarded in such tests. All defects which are rendered visible by the tests, and which can be traced to faulty execution or to the materials used, are to be remedied by the contractor within a period fixed by the building authorities. The tests for burden are carried out at the expense of the building authorities. The examination of the work with a view to its acceptance as a whole should take place within a given period of its completion. The contractor remains answerable for a certain period as to the normal condition and the good and proper execution of the work. It is suggested that a year is a suitable period.

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## ON WATER SUPPLY.

Papers read before the Conference of the Society of Arts on the Water Supply held at the International Health Exhibition in July.

From the "Journal of the Society of Arts."

### I.

### Water Supply in Its Influence on the Distribution of the Population.

BY W. G. TOPLEY, F.G.S., ASSOC. INST. C.E.

One of the most essential conditions for the comfort and well-being of a population is water, and a little consideration will show that the early settlements of a people have been where, and only where, water occurs.

In a broad and general sense, this fact is patent to all—the banks of rivers and streams are usually well populated—the wide areas of waterless districts are unpeopled; but the fact is equally true in a very limited and restricted sense, not at first so obvious.

The source of all water is the rain which falls on the land; this acts in two different ways, according to the nature of the soil on which it falls. If the soil is porous, or pervious to water, a certain portion of the rain sinks in; if the soil is impervious, the whole of the water either drains off the land into brooks, or passes back by evaporation into the air. The

water which soaks into a porous soil or rock, accumulates there until it flows out again as springs, or is artificially tapped, and drawn away by means of wells.

Springs occur near where a pervious bed overlies or underlies an impervious bed, or where a valley reaches down to the level at which the rock is saturated with water. In the case of valleys cutting deeply into the rock, the valleys themselves determine the level of saturation.

A soil which allows water to sink into it is a dry soil, and is, therefore, suited for habitation and for agriculture. Hence the main conditions which favor the settlement of a district are found in the same soil, or along the outcrop of the same bed. We thus see that geological structure controls the distribution of the population; not only in such great features of the earth's surface as mountain-chains, plains, and valleys, but also in the minor divisions of the district.

The outcrop of a narrow band of porous rock, between wide beds of clay, is strongly marked by the occurrence of a long line of villages, each of which obtains its water from shallow wells or springs. The cornbrash, between the Oxford clay and the great oolite clays, is an excellent example of this. So, too, is the marlstone rock-bed, between the upper and lower lias. Even a thin and comparatively unimportant bed of sand, ironstone, or limestone, if it only affords a small space fit for arable culture, will be marked by a line of villages. A thin bed of ironstone in the lower lias of Lincolnshire is a good example of this.

When rocks rise from beneath a covering of clay there are often springs at the junction.

The base of the chalk escarpment, with the line of outcrop of the adjacent upper green sand gives another good example. Here the villages always lie thickly along a definite line. There is a well-marked and constant relation between the outcrop of porous strata and the parish or township boundaries, the longer axes of the parishes crossing the outcrops more or less at right angles. A careful study of the distribution of the villages, and of the relation of their parish boundaries to the main physical features, throws much light upon the past history of the country, and often enables us to determine the relative ages of the settlements. This branch of the subject does not now concern us; we need only note that the arrangement of the parish boundaries depends upon the sites of the settlements, and that these are controlled by the outcrops of water-bearing beds.

The early settlements in England were nearly always controlled by such circumstances as have been here referred to; but the later development of special towns and districts has depended upon a variety of circumstances. In early times it was around some shrine of special fame or sanctity, or under the shadow of the castle of some powerful noble, that the population clustered and the town increased. A little later it was also in places especially well suited for various manufactures. Within the last 200 years the great development of our mineral wealth (especially of coal and iron) has entirely transformed the country. Large towns have sprung up over the coal-fields, often on wide tracts of clay, where few settlements would otherwise have taken place. The natural surface water supply of such places is often bad and small, and the mining operations frequently drain even this.

The water supply of modern towns is, in nearly all cases, either (*a*) obtained from a neighboring river, (*b*) brought from a distance, or (*c*) obtained from deep wells beneath the town. It thus, except in the first case, differs from that of the original settlement, which always obtained its water from streams, springs, or shallow wells. In far too many cases the primitive source of supply has been continued in use long after the time when it should have been abandoned; and the local source of water supply, essential to the early development of a town, has become a source of danger as the population has increased.

Of the points just mentioned, London affords an excellent example. The old parts of London and its suburbs are built upon gravel resting on London clay. Where small valleys (such as the Fleet) cut through the gravel, there are natural springs; but everywhere water can be obtained in shallow wells sunk through the gravel. So long as the inhabitants were dependent entirely upon these springs and wells, the houses were confined to the gravel; when a general sys-

tem of water supply was introduced, the population extended over the intervening area of clay. Meanwhile, the increasing population, without any adequate system of drainage, fouled the shallow wells, and rendered them all more or less impure. It is only within the last few years that some of these have been closed by authority.

Below the superficial deposit of gravel, there are other sources of water supply for London. The strata beneath lie in a basin-shaped form, and thus favor the accumulation of water. Underneath the London clay there are the lower tertiary sands, holding water which rises in the wells when these are sunk through the clay. Still lower, there is the great mass of chalk in which there is an enormous store of water. Still lower, and separated from the chalk by a bed of clay (gault), is the lower greensand. This, on the south side of London, may yet yield some water, but it can never be the great source of supply which was once hoped for.

There are, then, with the river, four different sources of water supply at or beneath London, each giving a different quality of water. Probably no large city in Europe is better situated than London for supplying itself with water from within its own area; but so vast has London now become, that all these taken together are insufficient, or inefficient.

It is a curious circumstance that some others of the great capitals of Europe are built on "basins" like that of London, and hence are able to obtain deep well-water from beneath. Paris, Berlin, and Vienna are good examples. This is a circumstance that could not have been known to the early settlers, who concerned themselves only with the surface sources of water supply.

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## The Origin of Water Supply.

BY G. J. SYMONS, F. R. S.

This title might possibly be supposed to imply a history of the past, but in this Health Exhibition, *pace* Old London, we deal chiefly with the present and with the future.

I know no better word than origin wherewith to describe the small portion of the great subject of water supply which I am permitted to discuss.

All water supply comes from the clouds, and it is with the products of the clouds as rain (including therein snow and hail) that I have to deal.

Perhaps, before describing the general features of rainfall distribution, it may be permissible to explain (for the use of those who have never done it) how the fall of rain is measured. If we imagine a flat dish—a tea-tray, for instance—placed upon a lawn during rain, it is obvious that (subject to loss by splashing) that tray would, at the end of the shower, be covered by a layer of water of a depth approximately equal to that which fell upon all portions of the lawn, and the depth of water on it (say ½ inch) would be the depth of the rain fallen. Obviously, besides the loss by splashing, the water on this tray would soon evaporate and be lost, besides which the depth could not easily be accurately measured. For these reasons, some form of funnel is always used, so that the rain may be, as it were, trapped, prevented from splashing out, and from evaporating. In the gauge before you (a very inexpensive one) all known sources of error are guarded against, and, as the water collected by a 5-in. funnel is measured in a jar only 1½ inches in diameter, it will at once be seen that its vertical depth is multiplied nearly tenfold, and, therefore, even one-hundredth of an inch is easily measured.

There are other patterns specially adapted for observation on mountain tops, where they can only be visited once a month; others for observations during heavy thunderstorms, so as to obtain data needful for drainage questions; others in which every shower that falls writes down its history, the instant of its commencement, its intensity during every minute, and the time of its termination; but I must not stand between you and other papers with a discourse on the many interesting points which these gauges bring out.

During the last 25 years I have done what I could towards establishing a complete system of recording the rainfall in this country. In early days the British Association for the Advancement of Science gave considerable help, but some ten years since they dropped it. Government have never given any help at all, and now the whole cost, or 99 per cent.

of it, is borne by the observers themselves, a body which has now grown to the very large number of nearly 3,000. I do not know the precise number, but there are every year new stations beginning, old ones stopping, and others interrupted; yet, for 1883, I have just had the pleasure of printing perfect records from 2,433 stations, every record having been previously carefully examined and verified.

Hitherto I have been so overworked, and my staff has been so small, that the discussion of the data falls behind the collection; for this reason I cannot lay before you such data as I wish. However, the map on the wall is the one I drew many years ago, and which was inserted in the sixth report of the Rivers Pollution Commission. It is not perfect, but as it is tinted with increasing darkness for places with heavy annual falls of rain, it will at least show you the broad features of the distribution over the country.

I refrain from going into the subject in detail, desiring chiefly that you should realize the fact that large tracts of country have twice and even three times as much rain as others. If we descend to single stations the differences are, of course, greater, *e. g.*, in 1883, the rainfall at the Stye, in Cumberland, was 190.28 inches, and at Clacton-on-Sea, in Essex, it was only 18.71 inches; that is to say, the one was more than ten times the other.

Here I should like to interpose a question as to public policy. There is often a great outcry if the water of one district is taken to another. Surely, while there is no relation whatever between the density of population and the quantity of rainfall, one early duty of a Government is to see that all parts are amply supplied with the chief necessary of life. Englishmen have a dread of centralization, but in many ways they pay a long price for their dread. At present it is not often that any town can even state before Parliament its views as to the effect upon it of what its next neighbor may be obtaining powers to do. Having suggested one semi-legal question, I may as well mention at once another. Up to the present time, there being no Hydraulic-office (as I hold that there should be) in this country, all the larger water questions come before Parliament as private bills, and, provided that they get through committee, they, as a matter of course, become law—law for all time to come. No one can foresee what will be the total population of this country a century hence. No one can tell where the bulk of the people will reside, nor what will be the need for water in various parts of the country. Water-rights are already very valuable, and they will probably become still more so. Would it be possible to safeguard our successors by insisting that special water-rights, if now asked to be created, shall be subject to revision, *without compensation*, after the lapse of 100 years?

However, to return to rainfall, and explain why I stated it to be the origin of water supply. All rain and melted snow must be disposed of, either by evaporation, percolation, or flow into streams and rivers. The first class, evaporation, is, of course, not a supply, and therefore we must not pursue it. Percolation is the source of all springs and of all well-water. Sometimes, as at Lancaster, the springs are so large that even a considerable town can be supplied by merely laying pipes to the sources whence they burst forth; sometimes they run into the reservoirs of gravitation waterworks; sometimes they pass, as in the chalk districts, for miles beneath impervious strata, finally being either pumped up from wells, or even, in rare cases, rising as true artesian wells above the surface of the ground; and sometimes they pass even deeper, as in the red sandstone supplies pumped from extreme depths for Liverpool and other towns.

The water which runs off the surface is sometimes utilized by throwing a bank across a stream, and thereby forming a reservoir behind it, as, for instance, in the new supply for Liverpool from the Vyrnwy, where the reservoir will form a lake larger than many of those in Cumberland. Sometimes the lakes themselves are utilized as reservoirs, as, for instance, Loch Katrine and the surrounding lakes, and sometimes, as at York and London, the rivers are drawn from by powerful pumping machinery.

It is often said that there are few things so uncertain as the rain. That is both true and false. True as regards

our ignorance of the future, false as regards our knowledge of the limits within which the quantity of rain will be found to vary.

There are now hundreds of records of rainfalls in this country of thirty or more years each, and in a very large majority of them it will be found that the following proportions will be within 7 per cent. of the truth:

Wettest year, 45 per cent. more than the average.

Driest year, 33 per cent. less than the average.

Driest two consecutive years, 26 per cent. less than the average.

Driest three consecutive years, 21 per cent. less than the average.

There are many other facts respecting the laws of rainfall distribution, concerning which time prevents my saying anything, but I trust that enough has been said to establish the necessity of a perfect system of rainfall registration as the basis of any efficient hydraulic organization.

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## Water Supply to Villages and Rural Districts.

BY EARDLEY BAILEY-DENTON, C.E., B.A., OXON.

I believe that I am uttering a fact which no one can discredit when I state that there is no object in social economy which is more important, having regard to the aggregate number of persons affected by it, than the supply of water to village communities and rural districts.

At the present moment, when the International Health Exhibition may help to draw attention to sanitary objects of varying degrees of importance, it may be well to make clear that the condition of rural districts, in relation to water—the first essential of healthy life—is a positive disgrace to a country represented by a State Department whose efforts, it appears to me, should be specially directed to the protection of small communities less able to help themselves than large ones; and is a sad reflection on the present advanced stage of sanitary knowledge—an admission which the special meteorological condition of the present season, and a possibility of a visit of cholera, brings home to all minds with increased force.

If it should be understood, too, that the existence of this condition of things is to be traced, not so much to the absence of potable water, or the difficulty of bringing it into use, as to the disinclination of local authorities to develop the capabilities at their command.

It may be said with truth that, as a general rule, Local Boards and Boards of Guardians having jurisdiction in rural districts, who have been called into existence to supply the sanitary requirements of those districts, are animated with less desire to perform the duties devolving upon them than to avoid them. It is, indeed, notorious that the majority of members of Local Boards are elected under a pledge to oppose such works as sewage and water supply, on the ground that the rates will be increased, and knowing this to be the case, and that few persons of superior position are willing to take part in Local Boards, because they would invariably be outvoted, it is easy to understand why rural districts should be the last to move in the water question. It is, however, very difficult to explain why the clergyman and medical man of rural parishes, whose higher education should be a guarantee that the right thing would be done, fail to exercise proper influence. If, perchance, they are elected to serve on Local Boards it almost invariably follows that the one forgets what he has said in the pulpit as to the influence on the future of sudden death; whilst the other ignores the advice he has given his patients in their sick-chamber in relation to the fatal effects of inhaling and imbibing those germs of disease which float in foul air and impure water. Directly they are easy in their chairs as members they content themselves with the *laissez faire* policy of their colleagues.

These influences explain how it is that local authorities abstain from appointing as surveyor, or sanitary inspector, any man with a capability and courage to expose local defects and requirements, and why, when a medical officer does his duty in explaining the defective character of the water supply of any portion of his district, some reason is soon found for relieving him of his duties, and for appointing another in his stead, the actual result of all this being that the governing bodies of rural and small urban

districts exercise their functions, when compelled to act, not by taking the advice and opinion of men technically qualified to guide them, but by the exercise of their own judgment. You may often observe a small publican or a grocer—excellent tradesmen in their respective vocations—directing the sinking of wells in village streets in close proximity to leaky sewers, ditches or cesspools, by which the water intended for the supply of the poorer inhabitants soon becomes foul and unsuitable for domestic use. So general, indeed, has been this abuse, that it is no exaggeration to state that nineteen out of twenty existing village wells are quite unfit for their purpose, and that if samples were honestly taken and submitted to a competent analyst they would be condemned. Yet they are permitted to exist, and nothing is said about them, because the populations interested are comparatively small, the death rate is not excessive, the dwellings are low in value, and, above all, because the rates would be increased if a proper water supply were substituted.

I have been induced to offer some remarks upon the present occasion, not because I have anything especially new to lay before you, but because the facts I have just referred to on the constitution of local authorities and the performance of their duties, have been made more pertinent by the circumstance that, at a time when there exists the apprehension of a visit of cholera, a scarcity of water may occur, owing to a remarkably dry winter being followed by an unusually hot summer, which the recent thunderstorms may not sufficiently counteract. It is unnecessary to explain that the summer supply of water is very greatly dependent upon the fall of rain during the preceding winter, *i. e.*, upon the rain falling in the non-evaporating and dormant months of November, December, January and February. The mean amount of rainfall in those months of the last winter did not reach two-thirds of the average quantity due to the same months for the preceding 60 years. This deficit would have been much more severely felt at the present time, and would have affected our subterranean supplies much more than it is now likely to do, had it not been in some measure counterbalanced by the excesses of rain which occurred during the last seven years, from 1876 to 1883, which gave us, on the whole, a considerable balance to carry over. This advantage, coupled with the frequent and heavy thunderstorms which have occurred within the last month or two, will go far to prevent the scarcity of water which would otherwise have occurred during the coming autumn; though, unfortunately, this national advantage will be a poor compensation to the agricultural interest, which has suffered so severely from the excessive wetness of the last few years.

Without taking into consideration on the present occasion the use of rain water, which, under careful management, may be collected from roofs and other impervious surfaces, and stored in tanks, and which will always form a valuable means of supply to private dwellings, and in special instances may be made available even for villages, our rural supply, now so often derived from dirty ditches and shallow wells, more or less polluted by foul matters, may, in the absence of springs, rivulets and impounded upland surface waters, be obtained from subterranean sources of "wholesome" character. These are to be found in various beds or outcrops of a water retaining character, which gather water at a comparatively shallow depth below the surface, such as the post-tertiary beds of Norfolk and Suffolk, and the different drift beds covering the London clay; the Bagshot sands, the green sand overlying the wealdon and gault clays, the surface sands and beds of the wealdon formation, the calcarious grit and coral rag outcropping between the Kimmeridge and Oxford clays, and other beds of like nature; or from the well-defined water-bearing strata of the chalk, the oolite, and the red sandstone formations which are deep lying, and to reach which it is often found necessary to pass through superincumbent impervious beds or strata of varying thickness.

From the first source it requires comparatively little motive power to raise the supply to the height required; in fact, in many cases, the application of the ordinary lift or atmospheric pump suffices; in others, where the depth exceeds thirty feet, additional power is called for. The second source requires more powerful pumping, and may involve

the use of several pumps working in unison. All this has been said and explained before. My desire now is, if possible, through the influence of this meeting, to impress upon Local Boards and Boards of Guardians in rural districts, where, in order to obtain unexceptional potable water, they are obliged to seek it beneath the surface, that the experience already gained in tubular wells goes far to prove that, in the majority of instances the "tubular" system may, with good effect, take the place of the old and more expensive practice of sinking large wells involving brickwork, steining and staging. Economy, important though it be, is however secondary to the more important fact that a tubular well signifies continuous and watertight piping from the surface of the ground to the subterranean water level beneath, so that the entrance of polluted surface or subsoil water (as is so frequently the case in ordinary shaft wells) is rendered impossible. In addition to this advantage, it should be pointed out that tubular wells are very rapidly made, and can be readily removed should it occur that the water found or sought has not answered expectations in quantity or quality. Moreover, the whole of the materials employed may be applied, when withdrawn, to the same purpose in another place.

I may here state that there are some few disadvantages attending the adoption of tube wells which it is right at once to refer to. One is, that if, owing to accident, pumping is stayed, there will be no supply during such time, and if it should happen that the stored supply should run out before the pumping is resumed, much inconvenience may be experienced; whereas in ordinary shaft wells, there being room for more than one pump, such an objection may be obviated. Another disadvantage is that should the demand for water increase beyond the capability of supply the only remedy is to sink others, and to utilize two or more in combination.

To render the nature and cost of tubular wells, which necessarily vary in character and size according to local circumstances, as intelligible as it is possible to make them to rural sanitary authorities, I may shortly state that, adopting for illustration, the two characters of the tubular wells already mentioned, *i. e.*, those that can be worked by ordinary lift and atmospheric pumps at a depth of less than 30 feet from the surface, and those that raise water by more powerful machinery from deep subterranean water-levels, the *modus operandi* and cost will be as follows:—

In the first instance, taking, as examples, cases where the populations may severally be 400 and 1,000, and where there exists a constant supply of water at 20 feet below the surface, recourse may be had to Norton's Abyssinian tube wells. The water is reached by driving tubes down through the ground to the water level. The first tube is pointed and perforated for a few inches with holes varying in size from $\frac{1}{8}$ to $\frac{1}{4}$ inch. Length after length of tubing is driven into the earth at the selected site, and each succeeding length is connected with the last by a screw joint. The perforations at the base are four times as much as is necessary to obtain the full flow of water from the tubes, and they are kept clear by an arrangement adopted by Messrs. Legrand and Sutcliff, of Bunhill Row, City, for forcing out any sediment or matter that may obstruct a free influx of water. This is effected by suddenly liberating a column of water after it has been raised to a sufficient height above its normal level. The number of tube wells required in a village of 400 would probably be two, and in one of 1,000 people probably five. From figures kindly given to me by the patentees it would appear that the capital expended in providing the wells and appliances will not exceed 2s per head of the population. Of course this only refers to the provision of the tubes, the pumps, and the cost of fixing them. There are many instances of small villages and hamlets where one well and pump alone would suffice; but there are others besides those given as illustrations, where a number of these wells may be necessary, and which should be united by means of a cast iron horizontal main or mains, with intervals between the vertical pipes, governed by the nature of the water-bearing seam out of which the water supply is obtained. This distance may vary from 18 to 30 ft. The motive power to work the pumps may vary in kind; water-power may be used when it is close at hand, or gas where it can he readily obtained.

In the second instance (deep sources), the tube wells consist of iron piping fixed in bore holes, which latter, in fact, form the well, with the piping to serve as the pump barrel and rising main, to raise the water into a service reservoir. These bore holes will vary in depth according to local features, and in diameter from 5 to 15 inches, according to the quantities of water to be raised. The core of pipes form as already intimated, a continuous tube from the surface of the bore hole to the water level below, and are made perfectly flush both inside and out, and must be watertight. They are sunk for a sufficient depth below the standing water level as to secure an effective discharge. The pump is fixed within the tubing, which forms a cylinder, and is connected with the engine on the surface by rods properly guided within the tube. Special pains are taken so to construct and fix the pump that it may be readily brought to the surface, repaired, and replaced. For the first 15 or 20 feet of the well a shaft 5 or 6 feet in diameter is necessary, in which to fix the necessary gearing connecting the engine with the pump, and to place the air vessel, &c., regulating the lifted supply to the reservoir. It would appear from figures supplied me by Messrs. Tilley, of Walbrook, for works which we have now in hand, that the primary outlay varies from £500 in a case where the lift is 100 feet, the supply 40 gallons per minute, the depth of the bore hole 300 feet, and its size 7 inches, to £750, where the lift is upwards of 250 feet, the supply 50 gallons per minute, the depth of the bore-hole over 300 feet, and its size 9 inches.

Besides tubular wells sunk perpendicularly into subterranean water, supplies may not infrequently be obtained by the use of siphons for drawing water out of water-yielding basins, to which there is no natural outlet, by deflected pipes laid over or through the rims of the basins. The extraction of the required supply is effected by dipping the shorter leg of the siphon into the water bed forming a ready-made reservoir, and carrying the larger leg into the village requiring the supply, to act, with proper appliances, as a service main. This automatic mode of raising and delivering water has already been found available for towns as well as villages.

In the cases of Abingdon and Warwick, a siphon arrangement has been found very beneficial. The firm to which I belong, when devising the water supply for the former town (under the immediate supervision of Mr. C. F. Gower), adopted this expedient for raising the necessary supply for a population of over 6,000, which we had intended to obtain from a direct adit driven into the bed of coral rag, or calcareous grit, outcropping between Boars Hill and Abingdon; but which we abandoned in favor of a suggestion from Mr. J. Thornhill Harrison, of the Local Government Board, who, at an inquiry held by him, pointed out that the water bed which we were making preparations to tap might be considered a natural reservoir, from which the required supply could be raised by means of a siphon passing over the bank impounding the water. This object was effected by means of a 9 in. pipe capable of discharging 330 gallons a minute, laid from a reservoir holding 125,000 gallons (which it was found necessary to make within the calcareous grit for storage and ready discharge), the bottom of which was 40 feet higher than the highest part of Abingdon. The shorter leg of the siphon is about 9 feet in length, and reaches very nearly to the bottom of the reservoir. When the water, finding its way out of the calcareous grit into the reservoir, rises above the crown of the siphon (which it generally does during the night), the discharge is by gravitation independently of the siphon; but when it sinks below that level, then the siphon action is called into play. This arrangement has been in existence at Abingdon for four years, without any hitch or difficulty of any kind.

At Warwick, Mr. Edward Pritchard, C. E., adopted a somewhat similar contrivance, whereby he effected a very great saving in the cost of the works. It has now been in operation for more than eight years, and is stated by Mr. Pritchard to work satisfactorily. Siphons, whilst working automatically, involve very little outlay in maintenance, and they would be adopted much more frequently than they are at present, if their special nature and advantages were more fully understood. They have been used with great advantage for the drainage of land, and for the lowering of water

standing in bogs. I may mention, as an illustration, that in Scotland the Earl of Stair drained by this means a wet marsh near Culhorn-house, which had rendered that residence unhealthy. The siphon-pipe (seven inches in diameter) was half a mile long, and it has drawn down the water nine feet.

There is yet another means of obtaining water for villages, which it would be wrong to exclude from the consideration of sanitary authorities, as in some instances, we know from experience already gained, that it can be resorted to with advantage; I refer to the use of waters from cultivated surfaces, which the Rivers Pollution Commissioners have designated "suspicious" waters. To raise them above suspicion they should be collected and filtered through a bed of natural soil, extending to about one pole (of superficial area) per head of population. By this means the water would be made very superior to that consumed by the majority of householders in rural districts. The preparation of filter-beds of natural soil is simple enough. A plot of land, as porous and free in its subsoil as can be obtained, should be selected, and made suitable by special treatment, at such an elevation relatively to the land from which the water would be obtained, and to the village which it is intended to serve, as will receive the off-flow from the former on its surface, and allow it, after it has passed through the filter, to collect in a storage reservoir, and thence to reach the village at a serviceable height. The filter itself should be deeply underdrained, and the water to be filtered through it evenly distributed over its surface. No manure whatever should be applied in it.

The water of underdrainage, when found to contain ingredients of an objectionable character, which the analyses of Professor Way have shown may be the case, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, rigidly preserved from the application of manure.

When we are taught by chemists to believe that the extraordinary purifying powers of aerated soil will render innocuous the discharged sewage of towns in which exists organic nitrogen in considerable amount, we must be satisfied that, by a second passage through natural soil, the water of underdrainage, already once filtered, may be freed from any putrescible ingredients it may have once contained.

This expedient is only suggested where a village being in the neighborhood of an estate which the owner has underdrained, such owner will allow the water to be diverted from a natural stream, and filtered before it is supplied for domestic use.

I will close this short paper by drawing the attention of sanitary authorities in rural districts to the "Reservoirs Act, 1877," by which powers are given to the owners of land to supply water "to any sanitary or other local authority" by contract, and to charge their estates with the outlay on works.

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## Water Supply.

BY EDWARD EASTON, M. INST. C. E.

The object of this paper is to put before the conference, in as concise a form as possible, the considerations which should govern the supply of water for domestic and other purposes, not with the intention of enunciating any new thing, but with the hope of drawing attention to well-recognized principles which are too often forgotten or neglected.

The three chief points which have to be considered in relation to this subject are:

1. The source of the water.
2. Its distribution.
3. The conditions under which it is used.

1. With regard to the source, it is evident that, in designing a waterworks, the engineer has to provide that the water shall be adapted to the purposes for which it is intended to be used, both as regards quality and quantity.

The question of quality will depend upon circumstances. It is essential, of course, that in every case the water shall be free from contamination by organic and other impurities; but the necessity of its being chemically free from other constituents will depend, to some extent, upon the purpose for which it will be used; for instance, in a manufacturing district, where the water is required for dyeing and such-like purposes, it must be free from certain mineral ingredients, whereas for the supply of

drinking water and for general purposes, this is a qualification which need not be insisted on.

It is now generally admitted that a soft water is preferable to a hard water, provided that the storage and distribution are properly carried out, and in every case where there is a choice of supplies, that which is soft, or which can be softened by simple means, should be chosen.

The process invented by Professor Clark for softening hard water by the deposition of a portion of the line, is of a very simple character, and it has been successfully adopted in many cases.

Sources of water, proper for use, may be classed under two distinct heads. 1st. Those which are afforded by nature in a state absolutely pure and fit for use, such as water drawn from wells and deep-seated springs. 2d. Those derived from water-courses or gathering grounds which are open to the atmosphere, and which must necessarily be exposed to the risk of contamination from external agencies.

In the case of the former, no works for storage or purification are necessary, the stratum of rock or other material from which the water springs, forming a natural reservoir and filter.

In the second case, it is necessary (*a*) that all direct pollutions shall be prevented from coming into the source; and (*b*) that in almost every instance, efficient means of filtration should be provided. The filtration ought, wherever it is found impossible to altogether prevent the chance of contamination, to include the use of some deodorizing agent, of which there exist more than one capable of practical application.

As instances may be mentioned the filtration at Wakefield, where, for many years, by the use of Spencer's magnetic carbide of iron, a water very much contaminated was rendered perfectly wholesome; and that at Antwerp, where Professor Bischof's spongy iron is employed with an equally good result.

2. Essential as it is to ensure that the source of supply is proper for the required purposes, it is equally essential that the mode of distribution shall be such as shall prevent its deterioration before being used.

To effect this, it is absolutely necessary that the reservoirs, into which the water is collected for distribution, should be covered, and that the mains and pipes should be perfectly air-tight, and laid at a proper depth below the surface, so as to preserve the water in its original state of purity, and, as much as possible, at the same temperature, during its passage from the source to the consumer.

One great cause of the complaints of the quality of the water in most large towns, is the use of cisterns for storing it in the houses, which it is impossible to employ without the risk of some injurious effect upon the water.

In the Session 1877–78, two bills were introduced into Parliament, at the instance of the Metropolitan Board of Works, for purchasing the undertakings of the London water companies, and for providing a separate supply of drinking water from the chalk. During the exhaustive examination of the waters supplied by the companies, made by the eminent gentleman who so fitly and ably occupies the chair, Sir Frederick Abel, assisted by Dr. Dupré, Mr. G. H. Ogston, Professor Voelcker, and the late able chemist of the Metropolitan Board, Mr. Keates, it was found that, whilst the water delivered in the mains was in almost every case excellent, the position and condition of the cisterns too frequently rendered it utterly unfit for human consumption. A great number of cistern deposits from all quarters of London were examined by these five gentlemen, with the general result just stated.

It is scarcely credible that the favorite place for fixing the cistern, from which the water for drinking and culinary purposes is drawn is immediately over the water-closet or next to the dust hole, whilst even in the better class of houses, where the cisterns are fixed in the roofs, they are very rarely sufficiently covered, and are open to contamination from soot, dust, inroads of black beetles, and other abominations. The latest researches of scientific men show that there is no more fruitful source of disease that such a condition of things affords. Although doubtless, a great deal has been done by the expansion of the system of constant service in London and elsewhere to remedy this frightful evil, the following extract from Sir F. Bolton's report for

the month of May shows that there is still much room for improvement. He says:

"In the monthly and annual reports on the metropolitan water supply, attention is drawn to the necessity which exists for a regular cleansing of cisterns, and also to the fact that contamination of water from gases generated by sewage is of far more frequent occurrence than is generally understood. Water pipes from cisterns are still to be found which are in direct communication with drains, so that gases may flow back into the cistern and become absorbed by the water. To prevent this an overflow pipe should be brought outside each house and the end left exposed to the air, instead of being carried into a drain, as is often the case. By the adoption of this plan poisonous effluvia and gases from drains will be got rid of, which would otherwise ascend through the pipe, and not only be partly absorbed by water in cisterns, but be mixed with the air in the houses, thereby becoming a cause of disease.

"The attention of consumers has been drawn to the fact that, in houses supplied on the constant system, all danger of drinking stale or contaminated water from cisterns may readily be avoided if the following recommendation is carried into practice, viz., to attach a small draw-off tap to the communication pipe which supplies the cistern from the main in the street, from which water may be drawn at any moment, day or night, direct from the works, thereby taking full advantage of any efforts made by the companies to purify the water to the utmost extent. This water should be used for drinking and cooking, and the contents of cisterns made use of for washing, flushing, baths, and similar purposes."

An abstract from these reports of the water examiner is printed by the companies at the back of the collectors' rate papers, so that no consumer of water can now be exonerated from the charge of negligence if this abuse is allowed to continue in his house.

3. This consideration naturally leads up to the third division of the subject, viz., the conditions under which water should be used. And first, it is essential that a constant supply should be given, without which it is difficult to avoid the deterioration of the water above alluded to.

Not only is it impossible to give an adequate supply by the intermittent system without having storage cisterns in the houses, but there is also a serious danger of contamination by the possible admission of foul air or gas into the mains when the water is turned off. There have been several instances of a water supply being seriously affected from this cause.

But to give constant service it is absolutely necessary, also, that the supply should be under proper regulations, which shall ensure the prevention of undue consumption and misuse of the water.

Not only are the difficulties of providing the supply greatly increased where waste is allowed to prevail, but the cost to the community is augmented without the slightest corresponding benefit to health.

Nothing is more fallacious than the idea, prevalent among a large section of consumers of water, that the allowing of taps and waterclosets to run to waste assists in the flushing and cleansing of the sewers, and therefore conduces to health. These continuous dribblings of water can have no effect whatever in removing any obstruction or accumulations which may exist in the large drains. The only proper and effectual way of removing fecal matter is so to regulate the use of water that it shall be proportionate to the work it has to do at the moment. Where this is done, by the use of properly constructed waterclosets, well-proportioned drains, and by keeping out from the system of sewers the rainfall on the streets and houses, the ordinary quantity supplied to a town is quite sufficient to perform this service without having recourse to extraordinary means. The question of dealing with the sewage of large communities, which is now so full of difficulty, would be much more easy of solution if these principles were more generally acted upon.

For these reasons, it is not desirable that the supply should be unlimited in quantity; on the contrary, every precaution should be taken to make that quantity commensurate with the real wants of the consumers.

It is quite certain that in almost every town a very large proportion of the water

delivered through the mains runs needlessly to waste.

To take an example on the largest scale, the quantity supplied to London, according to Colonel Sir F. Bolton's return for the month of May, amounts to 32 gals. per head per day, about 20 per cent, of which, or say 6 gals., it is estimated is used for other than domestic purposes, leaving 26 gallons per head as the quantity supposed to be absolutely consumed in the houses. Now it has been ascertained that, on the average, the water really required is not half this quantity; and there is also no doubt that, by taking proper precautions, the amount delivered can be made to approximate very nearly to the actual use.

At Liverpool, by means of careful inspection of fittings, aided by the use of Deacon's meter, a most ingenious arrangement, by which it is easy to localize, and therefore detect, waste, the consumption of water has been reduced from 33 to 22 gallons per head per day, and, within my own experience, the adoption of the same system has, in six or seven instances, produced even more satisfactory results.

The waste of water, whether it arises from leaky joints in the mains and service pipes, or from defective fittings inside the houses, can only be injurious to health from the increased humidity which is thereby imparted to the soil and atmosphere, and which, as is well known, contributes so much to the spread of infectious diseases and the establishment of epidemics.

At this moment, when we are suffering to a greater extent than usual from the contamination of the Thames, owing partly to the presence of a large quantity of sewage, but also to the abstraction of so large a proportion of the summer flow of the river, it is manifest that the reduction by 33 per cent. of the amount drawn from and discharged into the river would go far to ameliorate the condition of things now complained of.

Among the different proposals which have been made for the introduction of a system which would ensure the prevention of waste, is that of furnishing the supply by meter. This is open to the grave objection that, in order to save money, people would be tempted to go to the other extreme, and to content themselves with an insufficient quantity. To obviate this, some such arrangement as that proposed by the writer to the Select Committee of the House of Commons, over which Mr. Ayrton presided in 1867, might be effectual. The following extract from the evidence given before that committee will explain the proposal:

"I think a better method altogether might be devised of supplying the houses in London with water—a better system might be adopted to prevent waste. I should provide a constant service by meter, but under different conditions to any hitherto proposed. I think it could be designed with perfect fairness to the water companies and to the consumers, by making certain arrangements, and the general principle upon which I would propose that what should be done would be this: that there should be a sliding scale adapted to the class of house, each house should have a certain amount of water allotted to it. I would take a £100 house, and allot to it 150 gallons per day, and to a £200 house I would allot 300 gallons of water per day, and so on, upwards and downwards, provided that no house should have less than 50 gallons. Let the companies charge the same rate as they do now for that minimum quantity of water, and if more is consumed or passes through the meter the consumer would have to pay for that additional quantity."

Although at first sight the expense of the meters would appear to be prohibitive, both the consumer and supplier would soon be reconciled to the outlay, the one because he would know what he was paying in proportion to the water he received, and the other because they were only supplying water for which they were paid.

The consideration of the subject of this paper would not be complete without a reference to the important question of the conservancy of our rivers.

It is useless to discuss the method and conditions of supply, if the sources of water are not to be preserved to us, and it is quite certain that, with the immense growth of the population of this kingdom, it will not be long before this preservation becomes a pressing necessity.

In the report presented to Parliament by the Duke of Richmond's Select Committee on Conservancy Boards, in 1877, a very workable scheme was recommended by their Lordships. The Committee say that:

"In order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of Conservators, who should be responsible for maintaining the river, from its source to its outfall, in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general directions of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body, constituted of residents and owners of property within the whole area of the watershed."

But although the question of improving the water supply, by preventing the pollution of the rivers, was incidentally mentioned by their Lordships, it is evident that the main object of the report was the prevention of floods, and not the conservancy of water for the supply of populations. Now, it may well be said that the one subject is at least as important as the other, and just as the recurrence of a number of wet seasons at that time brought the question of the floods prominently before the Duke of Richmond's Committee, it may safely be asserted that a corresponding succession of dry seasons will compel the serious attention of the Government to the other part of the subject. We need go no further than our metropolis for the proof of this, for if, in addition to the saving of water by the prevention of waste, the flow of the Thames were properly regulated by works in the higher parts of its watershed, there is no reason why the river should not be in a condition which, although leaving very much to be desired in the way of improvement, would yet be tolerable, and, according to past experience, absolutely not injurious to health.

When presiding over the Mechanical Section of the meeting of the British Association, at Dublin, in 1878, on which occasion the opportunity was taken to very fully discuss, from a variety of aspects, this question of rivers conservancy, I made a suggestion which, I believe, is worth repeating at the present time. In my address to the Section it was stated:

"When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entails a monetary loss of several millions sterling in the three kingdoms; that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds; that there is a constant annual expenditure of enormous amounts for removing *débris* from navigable channels, the accumulation of which could be mainly if not entirely prevented; that the supply of food to our rapidly growing population, dependent as it is at present upon sources outside the country, would be enormously increased by an adequate protection of the fisheries; that the same supply would be further greatly increased by the extra production of the land, when increased facilities for drainage are afforded; that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

"A new department should be created—one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use, all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river-basin or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament."

It is earnestly to be hoped that no further time will be lost in passing an Act to deal with this subject, and that no

considerations of a party or private nature will be allowed to prevent a scheme of so important and imperial a character being made as complete and comprehensive as possible.

In conclusion, as I commenced by saying, I have not attempted to say anything new; indeed the subject has already been in the hands of far abler exponents than myself; especially would I refer to Dr. Frankland's very able and comprehensive Sixth Report of the Rivers Pollution Commission, the careful study of which is recommended to everybody who wishes to master the details of the question.

## SPONTANEOUS COMBUSTION IN COLLIERIES.*

By —. DURAND.

From Selected Papers of the Institution of Civil Engineers.

*Causes.*—The primary causes of fires breaking out in collieries where the coal is contaminated with pyrites are believed by the author, who is engineer of the Doyet Collieries,† in the department of Alier, France, to be the three following: Oxidation of pyrites, friction from slippings, and warmth of air current. Experiments made by Mr. Fayol have shown that above ground a heap of Commentry small coal, presenting to the air a surface of not more than about $1\frac{3}{4}$ square yard per cubic yard, will, if once it gets heated to a temperature that lies somewhere between 140° and 212° Fahrenheit, go on heating more and more till at length it takes fire.

Pyrite met with in coal-seams is either amorphous or crystalline, and occurs in the shape of nodules, flakes, bunches or veins, while sometimes it is so finely disseminated throughout the coal as to be invisible. In dry air and at low temperatures it does not oxidize; but its dissemination through coal or shale gives it a more porous character than appertains to it by itself, and in almost all cases it oxidizes in moist air and becomes converted into sulphate of iron, the excess of sulphur being set free. The heat developed by the oxidation is further augmented, where there is sufficient moisture present, by the subsequent conversion of the sulphate of iron into hyposulphate, with liberation of sulphuric acid, which, when mixed with one-quarter its weight of water, rises to the temperature of 220° Fahrenheit. Various other chemical actions also conduce to the development of heat; while there is no absorption of heat by the formation of any gas during the oxidation of the pyrites. At Doyet Collieries the roof over the thick seam of coal is composed in some places of fine shaly sandstone containing pyrites; and near the outcrop, where cracks have occurred in the roof, the moisture from the surface and the air from the mine, penetrating into them, have caused the roof to get red hot, and to set fire sometimes to the timber props. A mere bunch of pyrites, however small, occurring either in the coal itself or in a shale parting, is quite sufficient to serve as a lucifer match for starting a conflagration. The sulphur liberated by decomposition of pyrites burns at 480° Fahrenheit, and any sulpho-carbons which may also be formed burn at about 660° Fahrenheit; whilst the hydro-carbons of coal will not burn below 930° Fahrenheit at least. Hence pyrites, as furnishing the most inflammable products, are really what give the start to a fire.

Where pillars of coal become cracked and crushed under the pressure of the roof, slippings occur, producing considerable friction, which develops corresponding heat; and, as the surfaces sliding past each other are uneven, the friction and heat are concentrated upon the prominences in contact. The heat thus becomes sufficient not merely to accelerate the action of pyrites, but possibly to ignite coal seemingly free from

* The original article appeared in "Bulletin de la Société de l'Industrie Minérale," 1883, vol. xii., pp. 43-89.

† It will be borne in mind that in many of the collieries in the Midland and other coalfields of France the seams are not only of great thickness, sometimes even more than 20 yards, but are also inclined at steep angles, sometimes nearly vertical.—A.B.

pyrites, even anthracite hard to burn. In the open working at the outcrop at Doyet the coal has been set on fire by a sudden slip of the ground above.

An air current that was warmed by uncondensed steam discharged from an underground engine at Doyet caused a little small coal, which had accumulated against some timbering, to get so hot that the timber took fire after the engine had been at work rather more than three months. In return air-drifts the crushed coal in the roof is particularly liable to heat under the influence of the warm and moist current.

In seams free from pyrites the author believes oxidation of the hydro-carbons on exposure to air cannot develop heat enough to ignite the coal, and the only way in which he can account for spontaneous combustion in such coal is by the presence of dust or fine slack in the midst of any heaps that are found to be heating. Dust and fine slack he considers capable of exerting a condensing power upon the combustible gases that are ready to escape from bituminous or gaseous coal, and also upon the oxygen of the air; and the heat so developed may become sufficient to fire the gas, and thereby the coal.

While, therefore, spontaneous combustion may occur in any colliery, whether the coal contain pyrites or not, it is more particularly in seams of caking coal, containing pyrites that, as the workings progress, the pillars left standing grow hot rapidly, under the combined action of oxidation of pyrites, pressure and subsidence of roof, and oxidation of hydrocarbons through condensing power of dust. It is the pyrites, however, which, wherever present in any appreciable quantity, play the principal part in starting ignition, and thus constitute the primary cause of fire; the other causes are then but secondary, although they may so far supplement the start thus given as to make a seam containing but little pyrites appear readier to fire than one containing much more.

*Development.*—The development of spontaneous combustion is considered by the author firstly in the case of masses of coal, such as pillars left in working. Really solid pillars never fire; those that do are always fissured with numerous cracks, and are more or less crushed. Outbreaks of fire are encouraged by the presence of any coal crushed small, which, in its finely subdivided state, promotes the chemical actions that induce heating. Fire first smoulders at the bottom of the innumerable cracks by which the pillars have become fissured under the crushing load they have to support; then the walls of the cracks get red hot and burn, sometimes bursting suddenly into flame where the previous heating has covered them with bituminous matter. The tarry smell thus occasioned often betrays the existence of fire before it has become visible; and so difficult is it to find its actual seat, that often it is not discovered until it has crept outward towards the air current at the mouth of the chinks, and has ignited the crushed coal behind the timbering of the roads, and then the timbering itself. The danger is augmented wherever there are timbered excavations overhead; and still more wherever a timber drift has been pushed forward under a mass of crushed coal overhead. Through such a mass air circulates easily, heat and moisture collect there, and fire breaks out quicker than where the overhead coal has been got out previously.

Wherever crushed coal can be harbored on or amongst the rubbish that is packed into the goaf, fire is sure sooner or later to break out. It begins at some distance in from the roads, and creeps out gradually towards them, igniting on the way any timber that may have been left buried in the gob-packing; the pungent wood smoke gives immediate warning of the fire.

Pillars purposely left unworked, either for maintaining a shaft or because the coal in them is not good enough, are also liable to take fire. The road bears unevenly around them, they crush and crack under it, and small crushed coal accumulates next to the gob-packing; the heavier the pressure the sooner do the pillars heat and fire. Similar circumstances occur where a nip in the seam stops the getting of coal.

Where the goaf is not packed with rubbish, but the ground is left to fall in, there is certain to be fire if any crushed coal is left behind. The danger is liable to be enhanced by accumulation of explosive gas in the large cavities; as is the case also wherever cavities result from

settlement of rubbish packed in the goaf.

As to collieries being set on fire from a lamp or an explosion of fire-damp, the author considers this can only occur where the mass so ignited has got very hot beforehand, and is ready to catch fire in a moment. An explosion, moreover, throws down a lot of coal that will easily take fire, besides shaking and splitting the pillars, and so rendering them more ready to ignite.

Hard seams of caking coal, containing much gas and pyrites, are the most liable to spontaneous combustion. In very fiery seams the author has noticed that heating occurs generally in the dampest places, or along return air ways when the air is warm and moist. Where a pillar of bad coal had stood without heating for seven years at the foot of an incline in a current of fresh air from the downcast shaft, an alteration in the ventilation exposed it to the return current of warm moist air, and it then got so hot in two months as to necessitate its speedy removal; by the time it could be worked, it was already too hot to touch in some places.

The nature of the roof tells variably. In some collieries fire is found to break out more readily under a roof of tender shale than under one of thick, hard sandstone. At Doyet, on the contrary, the thick sandstone roof, settling unevenly after the workings, leaves roof cavities, in which air circulates and encourages heating; while in places where a ceiling of shale separates the coal from the thick sandstone, the shale falls, and no dangerous cavities are left.

Coal or rubbish tipped in heaps above ground from the pit mouth is liable to heat and fire by oxidation under the action of the air and wet, wherever the smaller stuff that collects at the top of the heap is combustible enough. The fire breaks out first a little below the top, on the side most exposed to the wind; and spreads thence throughout the entire tip. It is sometimes started direct from the braziers burning at the pit-mouth to light the landing of the cages; the tip then ignites first at the top, whence the fire spreads downwards and laterally.

*Prevention.*—If the coal in a seam could only be preserved from getting crushed and fissured by increased pressure in working, or at any rate if all access of air could be cut off from it when so injured, its spontaneous combustion would be prevented. In the rare cases of quarrying an outcrop, the coal, as long as the over burden can be removed, can be worked in successive courses or steps from the top of the seam downwards, and can thus be got whole throughout the entire thickness of the seam. If the over burden be sent down the pit to serve as rubbish for packing the goaf in underground workings progressing simultaneously, the open-air working can be continued to a somewhat greater depth: at the risk, however, of finding that the deeper coal so reached has been already injured by settlement due to the underground operations.

When coal is got underground in successive courses or steps, one below another from the top downwards, no packing in the goaf, not even were it masonry, will entirely prevent settlement of the superincumbent mass, whereby the coal in the lower and later-worked steps is always more or less crushed. A partial remedy consists either in packing with rubbish of a clayey nature, which consolidates into a more compact mass; or in leaving a sufficient thickness of coal underneath the packing of the goaf in the topmost course, and afterwards getting out as much as possible of this thickness, by working backwards below it and packing the goaf of the lower working also; or again, in timbering the floor of each course so thoroughly as to form a roof for the subsequent working of the next course below. But these methods, besides being costly and yielding a low output with a large proportion of small coal, are not always successful in obviating spontaneous combustion; still less so when the goaf is not packed at all, but is left to fall in.

What has to be guarded against is an actual outbreak of fire; so long as the coal is merely heating, the small quantity of noxious gas given off hardly matters, and the only drawback is that the workings sometimes get inconveniently hot for the men. The longer all risk of firing can be staved off, the more possible will it be to adopt the mode of working that will yield the largest output at the lowest cost, namely, in seams inclined at steep

angles, by laying out the workings in successive stages or panels of great height (measured up the slope), which entails less expense for the preparatory operations of laying them open; several of these stages are then worked simultaneously, the getting of the coal being proceeded with in each stage from the bottom upwards, by a succession of horizontal courses or excavations. By this method the bottom courses in each panel feel the roof-pressure least, and yield a great quantity of large coal, which is won without difficulty, and with less risk of heating and firing. But in the uppermost courses the coal gets more or less crushed by the augmented pressure; hence, to avoid fire there must be some limit to the total height of each panel, or rather to the number of courses contained in it, the bottom courses being of greater height than the upper. In a thick and well stratified seam of strong coal, containing not many partings, and inclined between 14° and 30° to the horizon, the total height of each panel may be 26 yards, measured up the slope, and the height of the bottom course 8 yards. But in the main seam at Doyet, which, though hard, is of variable quality and too liable to fire, the height of the courses is only that of a singe tier of timber props, say 2 to 3 yards. Here four courses can be got, and a fifth started, without any fire having broken out; only no course must take more than six months in getting, and all the goaf must be thoroughly filled in. Quick getting is indispensable for avoiding fire in seams that fire readily. Usually by the time the fifth course is reached, the broken coal it contains is already hot, and great care is needed to prevent its burning whilst getting; hence five courses would seem to be the general limit for the height of a panel. As soon as the third course from the bottom is being got in any panel, the getting can be started of the bottom course in the next panel below; if the working of the lower panel were begun sooner, that of the upper would be endangered by settlements.

Alike in laying out the roads and in getting the coal, care must be taken to avoid the formation of roof cavities, from which start cracks that radiate through the seam; such cavities are most liable to occur at junctions of roads, and are to be guarded against by careful timbering, which must be well watched. Large cavities occurring in spite of these precautions should be cleared out, and then thoroughly filled in with good packing of small rubbish brought from above ground. Where gob roads have to be kept open for working or ventilation, they should either be shifted so as not to run through the middle of the goaf, but along its margin; or else they should be walled thick enough with good packing impervious to air and moisture, particularly when used as airways. They should be kept at a safe distance from any crushed pillars that have been abandoned in working.

The advantages of packing the goaf with rubbish are, that the workings are thereby kept cooler, settlements are less expansive, pillars get less crushed, and are therefore less liable to heating, and fewer dangerous roof cavities occur in which an outbreak of fire would be difficult to extinguish. In packing composed of friable stuff, the smaller bits fill up the spaces between the larger; and, if of a somewhat clayey consistency, the whole compacts under the load into a solid mass impervious to air. Good packing of this kind should always be used in the bottom courses of each panel; then by the time the top course is reached in the next panel below, the coal will there be got under a roof as compact as solid sandstone.

Spoil got from stone-drifts should not be used for packing the goaf; the large blocks of stone are too hard to crush under any settlement overhead, and air can pass too freely amongst them. In working a panel where the bottom course had been wholly packed with spoil got from sinking a shaft and from driving stone-drifts, notwithstanding that the spoil itself was incapable of heating, the author found that pillars of considerable size, which had been left behind in the midst of this spoil because not worth getting, grew hot so rapidly as to be taking fire by the time the second course was finished and the third begun. It was only by then surrounding this dangerous goaf with small rubbish carefully rammed in, that the winning of the coal could be finished to the top of the panel. Some years later, when the working of

the next panel below came in under the same place, similar trouble from heating had to be encountered. Hence the author regards any spoil got underground as so bad for packing the goaf, that it should never be used unless the precautions are taken to pick out of it all stuff that could burn, and even then to keep it clear of contact with any masses that can heat. It is indeed by no means a dead loss to send up all such spoil to bank and throw it over the tips, where after two or three years' exposure to the atmosphere it may, if meanwhile prevented from burning, become good enough to send down again into the pit for use as packing.

The best packing of all consists of loamy earth, and surface strata more or less disintegrated; the former is necessary wherever access of air has to be stopped at once without waiting for the roof to settle down heavily upon the packing. Where the goaf is well packed with good stuff, the timbers, whether upright props or roof slabs, can be left behind to become crushed by the load and buried in the packing; otherwise they should be removed, even if only partially, as a precaution against fire. By way of rendering the rubbish tips at the surface sooner ready for use as packing, it is sometimes thought desirable to let them burn as freely as may be. But this opinion is not shared by the author, who considers that not only will a tip take a very long time to burn through to the middle, but that, after the fire has all burnt itself out, the ashy stuff will be too light, too dusty, too hot, and not binding enough, to be suitable for sending underground. Nevertheless even such burnt rubbish is preferable to spoil got underground and packed there at once.

Ventilation by a forced current of air under pressure has been found by the author to be favorable to spontaneous combustion. Whether compression or exhaustion be employed, the greater the difference of pressure between the entering and the return air-currents, the more readily will the air penetrate cracked and crushed coal, and thereby promote heating and firing. In this respect, sharp turnings or narrowing of roads, and air-doors situated in a strong current, in the midst of crushed pillars or badly packed rubbish, are sources of danger, as are also inclines rising steep, and upcast pits. Hence, wherever an inlet air-way runs at all near a return airway, the intervening pillars or ribs of seemingly solid coal require specially careful watching.

The coolness of the air current is practically of no value for preventing, though it may somewhat retard, the heating of cracked pillars, or of broken coal that has fallen from roof cavities or elsewhere. In a colliery where an old drift 4½ yards long, from a shaft to an inlet airway, had been closed with rubbish carefully packed, the subsequent settlement of the packing had left a space above, into which a little crushed coal had fallen from the roof; the coolness of the ingoing air did not prevent this slack from heating and beginning to burn; and it had to be all cleared out, and earth rammed in its place.

A return air-current should never have to go downhill, otherwise it accumulates heat and moisture at the upper end of the descent, thereby favoring spontaneous combustion at that place. Where distant workings are liable to be insufficiently ventilated, owing to negligence in maintaining former roads, now used as airways only, fresh air should be supplied direct to them, either by splitting the main ingoing current, or by sinking a new shaft from the surface. It is better to split the air than to course a single current through too great a length, because the latter means greater difference of pressure, attained with more risk of fire.

At the Doyet collieries, wherever the seam is not thick enough to work by the foregoing method of horizontal courses, and where the expense of laying out the workings on that method would be too great, the plan is followed of getting the coal in inclined courses, that is by pushing the working faces forwards uphill along the slope of the seam, instead of horizontally along its strike. The uphill courses however are more difficult to keep open, and are liable to worse falls; each course takes longer to get, so that the surrounding crushed coal runs greater risk of heating. And this risk is further enhanced by the augmented draught consequent upon the air-current passing up the slope from the lower to

the upper end of the course; hence. fire breaks out more readily, while it is also more difficult to contend with on the slope than in horizontal workings. On the other hand, the rather larger quantity of packing used in uphill than in horizontal courses is an advantage against fire.

Firing of slack-heaps above ground can be effectually obviated, in the author's opinion, only by completely precluding all penetration of air into them. To ventilate them, with the idea of keeping them cool, he considers as ineffectual and as dangerous as to let air penetrate crushed coal in the pit. From experience of its success in smothering fires on the sloping banks of out-crop workings, he recommends the expedient of covering the slack-heaps with a layer of refuse slimes from the coal-washers. such a covering, being coaly and not clayey, does not set hard and crack, but follows readily any subsidence of the stuff beneath it. A layer 12 inches thick he believes would be an ample protection against firing, or even heating; and he suggests that on shipboard spontaneous combustion in coal cargoes might be altogether obviated by a layer 6 inches thick. the coal being so stowed as to prevent the covering of slimes from disappearing into the interstices. To prevent spoil-tips from firing, the stuff should be tipped in a layer too thin to heat under the action of the air; and should be left long enough exposed, before tipping the next layer over it; if it be also freed beforehand from all that can be utilized, so much the better coal.

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## THE BAROMETER AND THE WEATHER.

### ABSTRACT OF A MANUAL ISSUED BY THE AUTHORITY OF THE METEOROLOGICAL COUNCIL.

From the "Nautical Magazine."

THE Atlantic Ocean will supply types of the winds usually met with in other seas. An area of high pressure occurs in the North Atlantic between the parallels of 30° and 40° north, and according to Buys Ballot's law, the wind draws round it, being northerly on its eastern, easterly on its southern, southerly on its western, and westerly on its northern side.

A seaman, therefore, outward bound from England, say, to the Cape of Good Hope, passes from the north-east to the east and south-east side of an area of high pressure lying to the westward of him, and as he approaches the coast of Portugal, the wind very generally comes from north-west, gradually shifting to north and north-east as he proceeds to the southward.

On the other hand, when a homeward-bound ship approaches the northern verge of the N. E. Trades, she finds that the wind draws to the eastward, with a rising barometer. As the area of highest pressure is reached the barometer ceases to rise, and the wind dies away. These are the dreaded "calms," or, as Maury calls them, "Doldrums of Cancer." There being no difference of pressure there is no wind, and these calms coincide with a large area of high and even pressure, where a ship will experience little or no wind until she has crept to a part of the sea where the pressure commences to decrease.

If, as occasionally happens, it is found that the N. E. Trade gradually turns into a S. E., S., and S. W. wind, it will be understood, from what has already been said, that a vessel experiencing these changes has passed round the S. W., W., and N. W. sides of this area of high pressure, thereby avoiding the region of calms altogether.

There is a similar area of high pressure in the South Atlantic, with a corresponding circulation of the wind round it.

The homeward-bound ship, after rounding the Cape of Good Hope, is at the polar edge of the S. E. Trade on the eastern side of the South Atlantic, just as the outward-bound ship is at the polar edge of the N. E. Trade when off the coast of Portugal, and the first wind she

experiences is from S. W., changing to S. and S. E. as she proceeds to the northward, which (according to Buys Ballot's law, when applied to the southern hemisphere), shows that she has passed along the S. E., E., and N. E. sides of an area of high pressure.

Again, the outward-bound ship, as she draws towards the southern verge of the S. E. Trades on the western side of the South Atlantic, very generally experiences changes of wind to N. E., N., and N. W., which are the winds met with in the southern hemisphere on the N. W., W., and S. W. sides of an area of high pressure, corresponding to the winds already noticed as being experienced on the western side of the North Atlantic.

Areas of high barometrical pressure occur in many other parts of the ocean, similar to those of the Atlantic, and corresponding winds circulate round them.

CYCLONIC GALES OF THE TEMPERATE ZONES.

The great currents of the atmosphere, which give rise to the prevailing winds, are thus seen to be regulated by the positions of the permanent areas of high and low pressure, and in these currents, subsidiary areas of low pressure make their appearance, and are carried along with them, and these traveling areas frequently give rise to gales.

In the temperate zone of the North Atlantic these gales, which almost invariably travel to the eastward with the prevailing atmospheric current from the west, generally commence at S. and end at W. or N. W., with little or no E. wind. The probable reason of this is that the areas of low pressure to which they are related have steep gradients only on their E., S. E., S., and S. W. sides, there being little or no difference of pressure between their center and the more permanent depression which lies to the north of them.

The ordinary gales of high southern latitudes are similar in character to those of the northern hemisphere. They also accompany areas of low pressure traveling to the eastward, and considering that an equatorial wind is here north instead of south, the winds are similar, for they commence at N., and end at W. or S. W., with little or no easterly wind, probably because the pressure to the S. is so much lower than that to the N. of the tract in which they occur.

The cyclonic storms of the Temperate Zones do not often present the phenomena of a central calm, with the winds blowing from nearly opposite directions on each side of it. There is, therefore, not so much risk of being taken aback as in the tropical cyclones; but it is advisable for a captain to know on which tack it will be safest to lie-to if obliged to do so, and this will be the same as that for the cyclones of the respective hemispheres.

The most serious sudden shift of wind which is to be expected in these storms is that from south-west to north-west in the northern hemisphere, or from north-west to south-west in the southern. This is generally accompanied by heavy rain or hail, with thunder and lightning, while the temperature falls several degrees with the first blast of north-west or south-west wind, as the case may be, according to the hemisphere.

In considering how to act in such circumstances, there are two matters to which the seaman's attention should be directed, as they seriously affect the conclusions he should draw from his barometer readings.

*The first* is that on the one tack his barometer has a tendency to rise, on the other it has a tendency to fall. The tack of rising barometer is the starboard in the northern, the port in the southern hemisphere. This may be explained as follows :—

According to Buys Ballot's Law in the northern hemisphere the lower barometer is on your left when your back is turned to the wind, and as when you are thus placed a ship on the starboard-tack is advancing towards your right, she goes towards the higher barometer and recedes from the lower. In the southern hemisphere this is reversed, and the ship on the port-tack advances towards the higher and leaves the lower barometer.

But this rule will only be strictly applicable so long as no change takes place in the barometric pressure, and it may so happen that a high pressure towards which the ship is going may be receding from her faster than she sails, and a lower pressure may be coming up astern and overtaking her; or it may be that a lower pressure towards which the ship is sailing may be moving away faster than she sails. Still the influence of the tack must

always be felt, and on the whole it may be said that in the northern hemisphere, a rising barometer on the starboard-tack is not sufficient indication of improving weather, and other signs should be looked for before trusting it. In all cases for the northern hemisphere a rising barometer on the port-tack is a valuable indication of improving weather, while a falling barometer on the starboard-tack is an important warning in the other direction. This order is reversed in the southern hemisphere.

*The second* point to consider is the relation which the course and the speed of the ship bear to the tracks and progress of the areas of low barometric pressure and their corresponding wind-systems, in parts of the sea where the general tracks of storms are known. This will be easily done by taking, as an illustration, the case of a steamer traversing the North Atlantic between England and America, where storms generally move in an easterly direction.

If a storm is advancing eastwards at the rate of, say, twenty miles an hour, and if the ship is steaming at the average rate of, say, ten miles an hour, the result will be that when going westward the ship will have a relative rate of motion towards the storm of thirty miles an hour, but when going eastward, of only ten miles an hour.

In other words, ships when outward bound across the Atlantic meet the advancing storm systems, which commonly travel from west to east, and when homeward bound run with them, consequently the rapidity with which the barometer falls or rises and the wind shifts is proportionately greater in the former case than in the latter.

### GALES OF THE NORTH TEMPERATE ZONE.

The ordinary gales of the north Temperate Zone commence at S. E. or S. and end at W. or N. W. If a ship in these latitudes experiences a fresh S. or S. E. wind, with a relatively high temperature and falling barometer, Buys Ballot's law shows that there is an area of low pressure to the W. or S. W. of her; and it is probably traveling to the E. or N. E. Experience shows that whether the ship be hove-to or stands to the westward, the barometer will fall until the wind shifts to the westward (which generally happens during a heavy shower of rain, together with a sudden fall of temperature), when the barometer will probably rise as fast as it previously fell, and a strong N. W. wind will set in.

From what has been said it will be clear to the navigator that in northern latitudes, at the setting in of a southerly wind, a sailing ship as well as a steamer bound to the westward will, by her course and speed, cause the barometer to fall quicker than if she hove-to or stood to the eastward, so that in this case also the state of the sea and other appearances ought to be considered, or her captain may be led to anticipate worse weather than is really coming.

With a southerly wind and falling barometer, a ship bound to the westward might gain by running to the northward with the object of causing the wind to back to the eastward, but the type of gale in which this is possible resembles a cyclone, and does not represent the ordinary gales of these latitudes which begin at S. and end at W. or N. W. Again, it might be possible for a ship, with the first of the southerly wind which exists on the east side of the area of low pressure, to get less wind by running to the north, but as the extent in latitude of the cyclone area is not known, and as there is no certainty that she would get into more moderate weather by doing so, she might do herself more harm than good.

It seems, then, probable that a ship bound to the southward or westward must face one of these gales if she meets it. A weak ship, whose object is to stem the sea and get safely through, without considering progress, should lie-to on the starboard-tack, as the wind generally shifts from S. to S.W., W. and N.W. This would of course be the best plan for any ship which found the gale too heavy for her. But a well-conditioned ship, bound to the westward, may keep on the port-tack until the wind shifts to west with a rising barometer, and then tack to the south-westward. This plan would, of course, tend to bring her into the trough of the sea, and she would be more likely to be caught aback as the wind changed, but we are assuming that her captain will be prepared to meet these risks.

When the wind has shifted to N.W. the starboard-tack takes her away from

the center of such a disturbance, though she may soon sail into the southerly wind of the eastern side of another low-pressure-area coming toward her. This would be a very common occurrence in winter.

GALES OF THE SOUTH TEMPERATE ZONE.

The prevailing gales of high southern latitudes resemble those of northern, and in describing them it is only requisite to remember that *there* north and south change places. For instance, as a ship bound to Australia gets into 40° S., "the Roaring Forties," she experiences a series of gales which, commencing at N. or N.E., end at W. or S.W. Now with a northerly wind in the southern hemisphere there is a low pressure to the westward, and the way in which the wind usually changes proves that those areas of low pressure are also traveling to the eastward. Ships which keep a steady westerly wind for days, as they run to the eastward in high southern latitudes, are probably keeping company with one of these areas of low pressure, and if they had hove-to or commenced beating to the westward they also would have experienced many changes, just in the same manner as our steamers bound *to* America do, whilst those *from* America frequently keep a steady barometer and westerly wind for days. This receives abundant confirmation from the frequency of the barometrical oscillations and changes of wind, experienced by ships bound to the westward, in rounding either the Cape of Good Hope or Cape Horn.

The best method for dealing with a heavy gale, or with a weak ship in an ordinary gale, is reversed for high southern latitudes; there the port is the "coming up" tack, which enables her to stem the sea, as the wind usually shifts from N. by N.W. to S.W., and the port-tack with a S.W. wind takes her away from the low pressure to which the wind is related, though of course it may, and in the winter months most probably will, soon take her into the northerly wind of the eastern side of another low pressure coming towards her.

For a ship beating to the westward, of course the best progress is made by keeping on the starboard-tack with the wind N. and N.W. until it shifts to W. and S.W., when she ought to tack to the north-westward; but it will be seen that, as in the best method for making progress to the westward in high northern latitudes, the ship will be headed off, and get into the trough of the sea; she will also be more liable to be taken aback, as the wind changes, than if she were on the port-tack.

TROPICAL STORMS.

HURRICANES, TYPHOONS, OR CYCLONES OF TROPICAL SEAS.

Of all atmospheric disturbances, of the approach of which the barometer can supply indications, and the dangers of which it may enable the seaman to avoid, by giving him warning of their proximity and position, the most serious are the revolving storms of the tropics.

These storms, all of which may be properly termed cyclones, occur in the three great oceans, the Atlantic, Pacific, and Indian Oceans; but they are seldom experienced within 5° or 6° of the Equator, and have not been traced into very high latitudes. They appear to be most frequent and most severe in the West Indies, in the vicinity of Mauritius, in the Bay of Bengal, and in the China Seas; and in these seas they are most prevalent during the months following the summer solstice, or in other words, from July to October, in the northern hemisphere, and in the southern from December to April. In the Arabian Sea and in the Bay of Bengal cyclones occur most frequently from April to June, and in October, November, and the beginning of December.*

* TABLE OF RECORDED HURRICANES, CYCLONES AND TYPHOONS, IN VARIOUS PARTS OF THE WORLD.

| | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| West Indies, 300 years..... | 5 | 7 | 11 | 6 | 5 | 10 | 42 | 96 | 80 | 69 | 17 | 7 | 355 |
| South Indian Ocean (39 years, 1809 to 1848)..... | 9 | 13 | 10 | 8 | 4 | — | — | — | 1 | 1 | 4 | 3 | 53 |
| Bombay, 25 years..... | 1 | 1 | 1 | 5 | 9 | 2 | 4 | 5 | 8 | 12 | 9 | 5 | 62 |
| Bay of Bengal, 139 years..... | 2 | — | 2 | 9 | 21 | 10 | 3 | 4 | 6 | 31 | 18 | 9 | 115 |
| China Sea, 85 years..... | 5 | 1 | 5 | 5 | 11 | 10 | 22 | 40 | 58 | 35 | 16 | 6 | 214 |

They are commonly known as hurricanes in the West Indies; cyclones in the Indian Ocean; and typhoons in the China Seas.

The space over which these storms have been known to expand themselves varies from twenty or thirty miles to some hundreds of miles in diameter; the wind blowing with an ever varying force, now lulling into little more than a strong breeze, and as the center is approached often rising into a blast of irresistable fury.

It is an invariable characteristic of their revolution, that the gyration of the storm field takes place in one direction; in the northern hemisphere in the opposite direction to the hands of a watch, and in the southern hemisphere with the hands of a watch. The knowledge of this law is the more important, as it not only supplies the seaman with direct means of distinguishing these storms from gales in which the direction of the wind varies little if at all, but it reveals to him the position of the center or vortex with respect to the place of his vessel, and therefore points out the way to avoid it, and so to escape from the region of greatest danger, where the fury of the wind is most extreme, the changes of its direction most sudden and the sea most to be dreaded.

In the Atlantic and South Indian Ocean these storms commence to the eastward; for some days they travel along a path not exactly west, but inclining a point or two towards the pole of that hemisphere which they are crossing; and as they advance they seem more inclined to curve away from the equator. When they reach the 25th degree of latitude, they generally curve still more, until they move to the N. E. in the northern hemisphere, and to the S. E. in the southern hemisphere. The Atlantic storms almost always wheel round to the northward in the Mexican Gulf, or in its vicinity, and follow the sea-board of North America.

The cyclones of the Bay of Bengal appear to originate near the Andaman Islands, those of the Arabian Sea near the Lacadives. These generally travel to the westward and north-westward, the former sometimes crossing the Indian Peninsula, sometimes passing off over Bengal, and curving back to the eastward. The typhoons of the China Seas commonly take a westerly or north-westerly course.

The rate of movement of these storms, though variable, may be averaged at 300 miles a day in the West Indies; in the Arabian Sea, in the Bay of Bengal, and in the China Sea, 200 miles a day; whilst in the Southern Indian Ocean their rates vary from fifty to 200 miles a day.

The indications of the approach of a revolving storm are the usual ugly and threatening appearance of the weather which forebodes most storms, and the increasing number and severity of the gusts with the rising of the wind. These signs are in some cases preceded by a long heavy swell, and confused sea, which comes from the direction in which the storm is approaching, and travels more rapidly than the storm center.

The best and surest of all warnings, however, will be found in the barometer. In every case there is great barometric disturbance, the barometer at the centers of some of the storms standing fully two inches lower than outside the storm field. Accordingly if the barometer falls rapidly, or even if the regularity of its diurnal variation be interrupted, danger may be apprehended.

The first care of a master of a vessel caught in a cyclone will be to find how the center bears from him. In the northern hemisphere let him, facing the wind, take eight points to the right of the direction of the wind, and that will be the approximate bearing of the center; in the southern hemisphere take eight points to the left. Thus, in the northern hemisphere with the wind from N. E., the center will bear S. E., and in the southern hemisphere with the wind from N.W., the center will bear S.W.

In the present discussion, the motion of the wind in a cyclone will, for the sake of simplicity, be treated as approximately circular. But this is not strictly the case, and there is evidence to show that frequently in some parts of the storm-field there is more or less indraft. At a considerable distance from the center, and before the barometer shall have fallen much below its normal value, the center may bear 10 or 12 points from the direction of the wind (reckoned to the right or left according to the hemisphere); but after *the barometer has fallen five or six-tenths of an inch* it is probable that the

wind then blowing forms part of the central storm circle, and the bearing of the center may be taken as eight points from the direction of the wind.

It was said that the master's first care will be to know how the center bears. His next care will be to know on which side of the storm's path his vessel is situated, and the direction in which the storm is moving. In the northern hemisphere if she be situated on the right-hand side or semicircle of a storm traveling to the westward—looking in the direction to which the storm is traveling—the wind will veer N.E., E., S.E., S., &c., or with the hands of a watch; on the left-hand side the wind will back N., N.W., W., &c., or against the hands of a watch.

Similarly, in the southern hemisphere, if the vessel be in the right-hand semicircle of a storm traveling to the westward—looking in the direction to which the storm is moving—the wind will veer S., S.W., W., &c., or with the hands of a watch; in the left-hand semicircle it will back S.E., E., N.E., N., &c., or against the hands of a watch.

In speaking of the shift of wind such a shift is meant as would be observed on a vessel hove-to; for if the vessel be moving faster than the storm, and in the same direction, the shift may be in the opposite direction to what has been stated.

If while the vessel is hove-to the wind be found to remain in the same direction, increase in violence, and be accompanied by a falling barometer, it is probable she lies in the path of the advancing storm—the most critical of all positions.

The wind in front of the storm-field is, from the nature of the case, directed across the path of the center; blowing towards the path on one side, and away from it on the other. Consequently, if we suppose the cyclone to be bisected by a line representing its path, a little consideration will show that in the semicircle on one side of the path, a ship running before the wind may probably be brought to cross the path of the storm in front of its center, and therefore under circumstances of the greatest danger; in the semicircle on the other side of the path a ship running before the wind will probably cross the path in rear of the center. The former of these semicircles has been called the "dangerous" semicircle.

When looking in the direction in which the storm is traveling the dangerous semicircle is always on the right hand in the northern hemisphere, on the left hand in the southern hemisphere; also in both hemispheres in the right-hand semicircle the wind, to a ship hove-to, always veers, in the left-hand semicircle it always backs. The semicircle with veering winds is the dangerous semicircle in the northern hemisphere; the semicircle with backing winds is the dangerous semicircle in the southern hemisphere.

The recurvature of the path always takes place towards the side on which the dangerous semicircle is situated, *i.e.*, to the right in the northern, to the left in the southern hemisphere. Hence in the northern hemisphere, so long as the vortex is traveling to the west, the winds in front of the advancing center are north-easterly; as the vortex turns to the north, the winds in front are easterly; and after it has turned to the eastward the winds in front are south-easterly. A similar sequence will arise in the southern hemisphere, but in the opposite order, the winds in front of the vortex beginning with south-east and ending with north-east when the vortex has turned to the eastward.

We derive, then, the following rules to find *the most dangerous wind*, supposing always that the track of the storm is such as is indicated above, recurving in about lat. 30° N. or lat. 26° S.—

NORTHERN HEMISPHERE.

Between the Equator and 30° N. lat.....N.E.
About 30° N. lat.....E.
Northward of 30° N. lat.....S.E.

SOUTHERN HEMISPHERE.

Between the Equator and 26° S. lat.....S.E.
About 26° S. lat.....E.
Southward of 26° S. lat.....N.E.

These winds are most dangerous, because in each case if the wind continues steady from that point and the barometer continues to fall rapidly the ship must be on the path of the storm and directly in front of it, so that she is in the position of greatest peril.

It is difficult to estimate the distance of the center of the vortex from a vessel.

This partly arises from the uncertainty as to the relation between the bearing of the center and the direction of the wind, and greatly from there being no means of knowing whether the storm be of large or small dimensions. If the barometer falls slowly, and the weather only gradually gets worse, it is reasonable to suppose that the center is distant: and conversely with a rapidly falling barometer and increasing bad weather the center may be supposed to be approaching dangerously near.

### PRACTICAL RULES FOR SEAMEN IN TROPICAL CYCLONES.

When in the region, and in the season of revolving storms, be on the watch for the premonitory signs. *Constantly and carefully observe and record the barometer.*

When there are indications of a cyclone being near, heave-to and carefully observe and record the changes of the barometer and wind, so as to find the bearing of the center, and ascertain by the shifting of the wind in which semicircle the vessel is situated. Much will often depend upon heaving-to in time.

When, after careful observation, there is reason to believe that the center of a cyclone is approaching, the following rules should be followed in determining whether to remain hove-to or not, and the tack on which to remain hove-to:

Northern hemisphere.—If in the right-hand semicircle, heave-to on the starboard-tack. If in the left-hand semicircle, run, keeping the wind, if possible, on the starboard-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the port-tack.

Southern hemisphere.—If in the right-hand semicircle, run, keeping the wind, if possible, on the port-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the starboard-tack. If in the left-hand semicircle heave-to on the port-tack.

Both hemispheres.—When the ship lies in the direct line of advance of the storm—which position is, as previously observed, the most dangerous of all—run. And in all cases act so as to increase as soon as possible the distance from the center; bearing in mind that the whole storm field is advancing.

Heaving-to in both hemispheres.—If the ship be in the right-hand semicircle, heave-to on the starboard-tack. In the left-hand semicircle, heave-to on the port-tack; these being the tacks on which the ship will "come up" as the wind shifts.

In receding from the center of a cyclone, the barometer will rise, and the wind and sea subside.

It should be remarked that in some cases vessels may, if the storm be traveling slowly, sail from the dangerous semicircle across the front of the storm, and thus out of its influence. But as the rate at which the storm is traveling is quite uncertain, this is a hazardous proceeding, and the seaman should hesitate and consider all the circumstances of the case, particularly observing the rate at which the barometer is falling before he attempts to cross.

*Cyclones of the South Indian Ocean.*—The researches of Mr. Meldrum, Director of the Government Observatory at Mauritius, have shown that, in the South Indian Ocean, a vessel approaching a cyclone on its southern side almost always encounters a strong Trade wind, which freshens to a gale. It is difficult to tell when the Trade forms part of the storm *circle;* consequently the bearing of the center can seldom, in this position, be inferred from the direction of the wind.

It is therefore recommended under such circumstances to heave-to and watch the wind and barometer; when the wind has shifted decidedly to the east or south the passage of the center with respect to the vessel's position may be approximately inferred; and when the barometer *has fallen six tenths of an inch* its height at the commencement of the storm, the bearing of the center may be taken as nearly at right angles to the direction of the wind.

If the wind shift from S.E. decidedly towards the south, run to the N.W. Or, if the wind remain steady at S.E., increase in force, the barometer still falling, it is probable the storm is advancing directly towards the vessel; in such case, the most dangerous of all, run to the N.W.

It is also stated that in the cyclones of the South Indian Ocean, north-easterly

and easterly winds often, if not always, blow towards the center. Such being the case, it is better to make as much easting as possible.

It might easily be shown, the same writer remarks, that all the homeward-bound vessels that put into Mauritius for repairs do so in consequence of damage sustained in a cyclone which they entered on its northern side. There is a strong temptation to such vessels to run on with a favorable breeze; but a freshening northerly or north-easterly wind, with a falling barometer, and threatening appearance of the weather, should warn them to heave-to in time.

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## PROGRESS IN MECHANICAL SCIENCE.

AN ABSTRACT OF SIR FREDERICK BRAMWELL'S ADDRESS TO THE MECHANICAL SCIENCE SECTION OF THE BRITISH ASSOCIATION.

From the "Journal of the Society of Arts."

AFTER alluding to the formation of Section H, Sir Frederick Bramwell said: At our jubilee meeting at York, I called the attention of the section to the fact that in 1831, when the Association first met in that city, they arrived there laboriously by the stage-coach, and that practically the Manchester and Liverpool, the Stockton and Darlington, and some few others, were the only railways then in existence. I also called their attention to the fact that in 1831 there were but very few steamers. I find the total registered in the United Kingdom in that year was only 447. If under this condition of things, the proposition had been made in 1832 at Oxford, as it was made in 1882 at Southampton, that the next meeting but one of the Association should take place in Montreal, the extreme probability is that the proposer would have been safely lodged in a lunatic asylum, for suggesting that that which might have involved a six-weeks' voyage out, and a four-weeks' voyage back, could ever be seriously entertained.

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There are those I know who object that Section G deals too little with pure science, too much with its applications. It may be, as the members of Section G might retort, that it is possible to attend so much to pure science as to get into the unchecked region of scientific speculation. . . . I think all men, even although they be followers of science in its purest and most abstract form, will concur in the propriety of Section G dealing with engineering subjects generally as well as with abstract mechanical science. Once admitting this, I may ask—certain what the answer must be—whether there is any body of men who more appreciate and make greater use of the applications of pure science than do the members of this Section. Surely every one must agree that we engineers are those who make the greatest practical use, not only of the science of mechanics, but of the researches and discoveries of the members of the other sections of this Association.

*Section A* (*Mathematical and Physical Science*).—The connection between this section and Section G is most intimate. With any ordinary man I should have referred, in proof of this intimate connection, to the fact that the President of A this year is a member of the Council of the Institution of Civil Engineers; but when I remind you that it is Sir William Thomson who fills this double office, you will see that no deduction such as I have hinted at can be drawn from his dual functions, because the remarkable extent and versatility of his attainments qualify him for so many offices, that the mere fact of his holding some one double position is no certain evidence of the intimate connection between the two. But setting aside this fact of the occupancy of the chair of A by a civil engineer, let us remember that the accomplished engineer of the present day must be one well grounded in thermal science, in electrical science, and, for some branches of his profession, in the sciences relating to the production of light, in optical science and in acoustics; while in other branches, meteorological science, photometrical sci-

ence, and tidal laws are all important. Without a knowledge of thermal laws, the engineer engaged in the construction of heat motors, whether they be the steam-engine, the gas-engine or the hot air-engine, or engines depending upon the expansion and contraction under changes of temperature of fluids or of solids, will find himself groping in the dark; he will not even understand the value of his own experiments, and, therefore, will be unable to deduce laws from them; and if he make any progress at all, it will not guide him with certainty to further development, and it may be that he will waste time and money in the endeavor to obtain results which a knowledge of thermal science would have shown him were impossible. Furnished, however, with this knowledge, the engineer starting with the mechanical equivalent of heat, knowing the utmost that is to be attained, and starting with the knowledge of the calorific effect of different fuels, is enabled to compare the results that he obtains with the maximum, and to ascertain how far the one falls short of the other; he sees, even at the present day, that the difference is deplorably large, but he further sees, in the case of the steam engine, that which the pure scientist would not so readily appreciate, and that is, how a great part of this loss is due to the inability of materials to resist temperature and pressure beyond certain comparatively low limits; and he thus perceives that unless some hitherto wholly unsuspected, and apparently impossible, improvement in these respects should be made, practically speaking, the maximum of useful effect must be far below that which pure science would say was possible. Nevertheless, he knows that within the practical limits great improvements can be made; he can draw up a debtor and creditor account, as Dr. Russell and myself have done, and as has been done by Mr. William Anderson, the engineer, in the admirable lecture he gave at the Institution of Civil Engineers in December last on the "Generation of Steam and the Thermodynamic Principles Involved." Furnished with such an account, the engineer is able to say, in the language of commerce, I am debtor to the fuel for so many heat units, how, on the credit side of my account, do I discharge that debt? Usefully I have done so much work, converted that much heat into energy. Uselessly I have raised the air needed for combustion from the temperature of the atmosphere to that of the gases escaping by the chimney; and he sets himself to consider whether some portion of the heat cannot be abstracted from these gases and be transmitted to the incoming air. As was first pointed out by Mr. Anderson, he will have to say a portion of the heat has been converted into energy in displacing the atmosphere, and that, so far as the gaseous products of the coal are concerned, must, I fear, be put up with. He will say, I have allowed more air than was needed for combustion to pass through the fuel, and I did it to prevent another source of loss—the waste which occurs when the combustion is imperfect; and he will begin to direct his attention to the use of gaseous or of liquid fuel, or of solid fuel reduced to fine dust, as by Crampton's process, as in these conditions the supply may be made continuous and uniform, and the introduction of air may be easily regulated with the greatest nicety. He will say, I am obliged to put among my credits—loss of heat by convection and radiation, loss by carrying particles of water over with the steam, loss by condensation with the cylinder, loss by strangulation in valves and passages, loss by excessive friction or by leakage; and he will as steadily apply himself to the extinction or the diminution of all such causes of loss, as a prudent Chancellor of the Exchequer would watch and cut down every unproductive and unnecessary expenditure. It is due to the guidance of such considerations as these that the scientific engineer has been enabled to bring down the consumption of fuel in the steam-engine, even in marine engines such as those which propelled the ship that brought us here, to less than one-half of that which it was but a few years back. It is true that the daily consumption may not have been reduced, that it may have been even greater; but if so, it arises from this, that the traveling public will have high speed, and at present the engineer, in his capacity of naval architect, has not seen how—notwithstanding the great improvements that have been made in the forms of vessels—to obtain high speed without a

large expenditure of power. I anticipate, from the application of thermal science to practical engineering, that great results are before us in those heat motors, such as the gas-engine, where the heat is developed in the engine itself. Passing away from heat motors, and considering heat as applied to metallurgy, from the time of the hot blast to the regenerative furnace, it is due to the application of science by the engineer that the economy of the hot blast was originated, and that it has been developed by the labors of Lowthian Bell, Cowper and Cochrane. Equally due to this application are the results obtained in the regenerative furnace, in the dust furnace of Crampton, and in the employment of liquid fuel, and also in operations connected with the rarer metals, the oxygen furnace and the atmospheric gas furnace, and, in its incipient stage, the electrical furnace. To a right knowledge of the laws of heat, and to their application by the engineer, must be attributed the success that has attended the air-refrigerating machines, by the aid of which fresh meat is at the end of a long voyage delivered in a perfect condition; and to this application we owe the economic distillation of sea water by repeated ebullitions and condensations at successively decreasing temperatures, thus converting the brine that caused the Ancient Mariner to exclaim, "Water, water everywhere, nor any drop to drink," into the purest of potable waters, and thereby rendering the sailor independent of fresh-water stowage.

Sir Frederick Bramwell then proceeded to refer to the application, by the engineer, of electrical science, and to several other of the subjects dealt with in Section A. He then treated of the relations of mechanical science to the other sections, and concluded with these words:

I trust I have now established the proposition with which I set out, viz., that not only in Section G, the section of mechanical science, but it is emphatically the section of all others that applies in engineering to the uses of man the several sciences appertaining to the other sections; an application most important in the progress of the world, and an application not to be lightly regarded, even by the strictest votaries of pure science, for it would be vain to hope that pure science would continue to be pursued if from time to time its discoveries were not brought into practical use.

Under ordinary circumstances I should have closed my address at this point, but there is a subject which at this, the first meeting of Section G after the meeting at Southport, must be touched upon. It is one of so sad a character that I have avoided all allusion to it until the very last moment, but now I am compelled to grapple with it.

In the course of this address I have had occasion to mention several names of eminent men, many of them happily still with us, some of them passed away; but I doubt not you have been struck by the absence of one name, which of all others demands mention when considering physical science, and still more does it come vividly before us when considering the application of science to industrial purposes. I am sure I need not tell you this name, which I can hardly trust myself to speak, is that of our dear friend William Siemens, whose contributions to science, and whose ability in the application of science, have for years enriched the transactions of this section, and of Sections A and B, for in him were combined the mechanic, the physicist, and the chemist.

But a brief year has elapsed since he quitted the presidential chair of the Association, and, with us at Southport, was taking his accustomed part in the work of this and of other sections, apparently in good health, and with a reasonable prospect of being further useful to science for many valuable years to come. But it was not to be; he is lost to us, and in losing him we are deprived of a man whose electrical work has been second to none, whose thermic work has been second to none, and whose enlarged views justified him in embarking in scientific speculations of the grandest and most profound character. Whether or not his theory of the conservation of the energy of the sun shall prove to be correct, it cannot be denied that it was a bold and original conception, and one thoroughly well reasoned out from first to last.

I feel that were I to attempt anything like the barest summary of his discoveries and inventions, I should set myself a

task which could not have been fulfilled had I devoted the whole of the time I had at my command to the purpose. I had, indeed, thought of making his work the subject of my address, but I felt that his loss was so recent that I could not trust myself to attempt it. There is no need for me to dwell further upon this most painful topic. He was known to you all, he was honored and loved by you all, and by every member of this Association he had so faithfully served, and over which he had so ably presided; and he enjoyed the respect and esteem of the best intelligence of England, the land of his adoption; of the Continent, his birthplace; and of Canada, and of the United States, whose populations are always ready to appreciate scientific talent and resulting industrial progress. It is not too much to say that few more gifted men have ever lived, and that with all his ability and talent he combined a simplicity, a modesty, and an affectionate disposition that endeared him to all.

I am sorry to conclude my address to you in this mournful strain. I have endeavored to confine my allusions to our dear friend within the narrowest limits, but if I have overstepped these I trust you will forgive me, remembering that "out of the fullness of the heart the mouth speaketh."

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## LAKE MŒRIS AND THE PYRAMIDS.*

By COPE WHITEHOUSE.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN 1881, during the York meeting of the British Association, a paper was read under the title of The Topography of the Pyramids and their connection with Lake Mœris, the Bahr Jousuf, Labyrinth and Sphinx. It was shown that if the accounts of the ancient historians were treated as the honest efforts of intelligent men to describe what they had seen and heard there was no difficulty in blending their facts into a harmonious whole. The result, however, was so stupendous in its area of operations, the amount of human labor, the boldness and originality of the engineer, the wisdom of the government and the patience of the nation, that it could not be readily grasped, even by minds accustomed to the greatest works of centralized power. It was far easier to deny than to comprehend it. There are apparent contradictions in every great advance in knowledge. Light without smoke or heat has recently been obtained by electricity. The corridor of an Egyptian sepulcher, lined with colored *bas relief's* carved on fine-grained limestone after these blocks had been placed in position, had, for thousands of years, proved to the world by an ocular evidence which none could deny, that light could be separated from all that tended to impair health or injure works of art by imperfect combustion.

Ancient authors had agreed in describing a reservoir of Nile water, formed artificially, fifty miles to the south of Memphis (Cairo), and twenty to the west of the Nile Valley, with 450 miles of indented sea-coast, containing islands, teeming with 22 sorts of fish, fed by a canal with double mouth, filled each year from high Nile. The water, stored by dams or levees, which it cost $70,000 annually to open and replace, was allowed to flow over the fields at low Nile for irrigation, or carried by tortuous, secret, subterranean channels into the local reservoirs of distant towns. "Mœris," they said, whether *meri* the beloved, or *Mer-uer* the great sea (cf. *mare* Lat. *mer* Fr.) was the grandest triumph of man over nature accomplished in all the long period of Egyptian history marked by rock-hewn temple, obelisk, or colossus, and throughout the length of the river from the Soudan to the Medi-

* This paper was withdrawn from the regular programme of Section E. of the American Association for the Advancement of Science, because it required lantern slides, and was read in the Academy of Music, Philadelphia, September 10th, and repeated (by request) in the Theatre of the Union League Club, September 12, 1884. The subject was presented to the New York Academy of Sciences, and discussed March 24, (see *Critic*, April 5th), and to the American Society of Civil Engineers, Buffalo, July 12. (See Reports in *Engineering* and other Journals).

terranean. "But," said the modern Egyptologists with absolute accord, "no such Mœris ever existed." There are, it was explained, the remains of dykes on the upper plateau of the Fayoum, which show that a pond or pool covering about 65 square miles was at one time formed and used to irrigate that province, and M. Linant de Bellefonds had, it was said, rendered the world a service in exposing the errors and absurd exaggerations of Herodotus, Strabo, Diodorus and Pliny, allowed to pass uncorrected, or repeated, by Ptolemy, Stephen and the geographers of Alexandria and Constantinople. The Bahr Jousuf was shorn of its antiquity and reduced to a work of Saladin (*Encyc. Brit.*). The Labyrinth became, under the exploration of Dr. Lepsius, a pile of mud bricks of no importance, with the scant remains of a small temple. The Sphinx nevertheless continued to smile impassively and offered itself as an impenetrable riddle to philologist and historian, astronomer and engineer.

Three years ago, therefore, if each of the factors of this whole was closely examined, its importance and character defined by the latest researches, and the accepted conclusions of recognized experts substituted for the terms used by a Strabo or a Pliny, the splendid fabric, reared high above modern thought and modern attainment, seemed to have been a distorted reflection in the mirror of tradition, seen by men who lent a credulous eye and eagerly transmitted fables founded upon truth, but on so scant a measure of it, that a tenth or a hundredth became a standard division by which to reduce their dimensions to actual fact.

As the objections, however, to the ancient authors were successively examined it became evident that no serious impression had been made upon their credibility. The acuteness of Voltaire and the geology of Linant Pacha were equally at fault. Bunsen, bewildered by the personal assurances of Dr. Lepsius, lost himself in a Labyrinth which was pure fiction. Centuries before the Crusades, the Canal of Joseph was a familiar word in Arab legend, and a measure of human enterprise in irrigation works in the Valley of the Euphrates. The map of Egypt in 1881 was a blank, where a deep dry southern basin has since been found. In 1882 and 1883, accordingly, researches had been made which gave to Lake Mœris all the attributes ascribed to it, in papyrus and on parchment, in picture, legend, and sober history.

It followed as a direct consequence from the rehabilitation of Lake Mœris that other assertions were restored to importance. If there was a lake 300 feet deep, there was also an island "as near as may be in the middle, with two pyramidal summits, 600 feet in height from the bottom of the lake, and 300 feet from the surface of the water" (Herodotus). The king who made the lake had "left a place" and constructed a tomb together with two pyramids. The piles of stone by which the upper half of this mass of rock was *revetted*, or into which it had been quarried and shaped, served by their height to show to those who sounded the shallow eastern plateau that it sank into a deep erosion (*fossa grandis*, Pliny) under the steep shores of horizontal limestone which bounded it on the west. On the first publication of these discoveries in Paris, in the *Revue Archéologique* (*Juin*, 1882) and in London, in the *Proceedings of the Society for Biblical Archæology* (June 1882) sections across the Nile Valley were given. One of these has been reproduced in the *Century* (October 1884). These show that the popular conception of Egypt above the Delta as a plain is entirely erroneous. The ancients invariably spoke of the two sides of the Valley as the Arabian (eastern) and Libyan (western) mountains. These steep cliffs of 400 to 800 feet are not the result of any upheaval. The dead level of the Libyan Desert is the last stratum of a cretaceous deposit, through which the waters of the Abyssinian highlands and Equatorial Africa have cut their way. The Nile now flows along the eastern shore of the cañon, and fills the lower level of it when high. To the west there are old channels, deeply scored by waterfalls in beds now dry, which are as much as 300 feet below the river and 200 feet below the sea. Everywhere scattered throughout this Libyan Desert are hills, pyramidal in form, with the axis in the line of erosion, with their bases sometimes 200 feet below the Mediterranean, but often rising as much as 800 feet above the valley of the Nile.

In the Wadi Reian the southwestern

basin of Lake Mœris, there is a hill, never before visited, known as the Haram. This word is applied exclusively to Pyramids by the Arabs. This hill is not a pyramid, but, like the island in the present lake, it justifies the ancient authors by affording a proof that "a place might be left" (by erosion) where a structure 600 feet high could be formed with a small amount of labor to serve as a monument of the immense natural wealth added to Egypt by the construction of its vast storage reservoir. If the Pyramids are to be treated as a class it is evident that a common factor must be found for them. It is difficult to assign them definite attributes. Prof. Perrot has, with great clearness shown that neither shape, dimensions, material nor purpose seem to have been their *raison d'être*. It has been insisted that the *first* of Gizeh, commonly called Cheops is an ideal pyramid and that the others are imitations. This opinion is only entertained by those who find mysterious significance in its corridor and coffer or sarcophagus. There is one factor which had necessarily been overlooked, all the pyramids are now seen to be (or to have been) either in, at, or near Lake Mœris and on the terrace above the high-level canals and aqueducts which were the conduits of its precious water. The Pyramids in the Nile Valley (like those in the lake) are lower than the level of the desert and are parts of islands or isolated hills formed by erosion before the Nile had cut its way at its present level between the commanding heights of Abu-Roash, crowned with a low pyramidal structure containing chambers in the live rock similar to Cheops, and the Mokattam with the citadel of Cairo, its extraordinary well and legends. The pyramids in Mœris were 600 feet high and yet natural hills. Medoum, the most southerly of the Pyramids is, like Abu-Roash the most northerly, only a hill, squared into shape and protected by walls of hewn stone. Its chambers are far above the valley and within the stone casing. They are, nevertheless, like every other chamber found in or under every other pyramid except Cheops, wholly in the natural rock. The two pyramids of Gizeh cannot be dissociated. They are termed *the twins*, and they have borne a fraternal relation from their first appearance in history. "They are," said Pliny, "on the African side on a barren stony mountain," but Strabo, with an accuracy in which he had been preceded by Herodotus, described them as *in* the brow of a hill, and not on its summit. This hill is over 150 feet above the plain. It rises within Cheops a certain height, not less than 40 feet above the socket stones which have been regarded as the base of the structure. It also rises to a much greater height at its western summit and sinks again abruptly to nearly the level of the Nile. North and south it is bounded by ravines, so that if the Nile rose but a few feet higher, the hill of the Gizeh plateau with its pyramids would become an island. If a horizontal plane be passed through the summit or even through the apex, supposing that the sides were coated and carried to a point, it would not be as high as Abu-Roash, 5 miles to the north, the Mokattam, 8 miles to the east, or the Kom el-Kashab, 9 miles to the west. Opposite to Gizeh, on the east bank of the Nile are immense subterranean quarries, about 100 feet above the plain. It was a natural inference that the stone of the Pyramids had been taken from these quarries. But it is evident that this cannot have been the case. Apart entirely from the obvious absurdity of sending to the opposite side of a swollen stream, 8 miles wide, for material which lay at hand and which was good enough for every purpose, and deemed quite good enough to use in every other pyramid on the west bank, the stones now visible on the exterior of Cheops could not have been quarried in the interior of a hill. Many of these blocks are deeply pitted or worn by water. They show marks of exposure to a disintegrating agent infinitely more powerful than the feeble action of sun or wind with an occasional shower. They are parts of the crust of a limestone hill, roughly broken perpendicularly, retaining their natural horizontal surfaces as each layer could be pried off any of the exposed edges of the strata of rock, laid bare and worn by the waters at their old level. It is therefore not a question of probability merely but approximates to an absolute demonstration that these twin masses of coarse and worthless limestone, broken into convenient blocks and piled without regard to any consideration except stability and the angular form which would protect the adjacent terrace

from hot winds, laden with sand, could, with due regard to the ordinary operations of the human mind, the geological conditions of the rock, the engineering methods of the ancient world and similar structures still standing, have been formed out of natural hills, each block moved but a short distance, usually downwards, into chambers quarried in the hill itself, until a solid mass was made as the quarrymen "backstoped" upwards through the hill. They could then return over the outside, using the crust as a revetment and making a Pyramid which only differed from Medoum by the increased labor due to the frail character of the original hill, honeycombed with sepulchral chambers, temples or quarries. All tradition confirms this. "I have built the Pyramids," said Surid, "to provide against the dreadful consequences of the Deluge which is to overwhelm the earth." But it was *Mœris*—the great sea—of which, the two Pyramids in the lake, 600 feet high, were also monuments, which saved the Delta from the dread scourge of the annual flood. Hermes "brought the people from the mountains where they had retired for fear of the waters, and taught them to cultivate the plains." In these traditions as well as in the statement of Herodotus that these pyramids were built "from above," were completed "outwards," by a king who shut *down* the (rock-hewn) temples," at an uncertain date, for "all the authors do not make it clear who built them" (Pliny), and the silence of the Egyptian records, geographical, historical and poetical, led the author of this paper to affirm as a probable conclusion from well-established facts, in accordance with the principles of sound reasoning, that the huge piles at Gizeh are the results of a creditable effort to convert an unsightly and dangerous hill into a solid mass with some further purpose which modern science has not fully grasped.

The various steps in this argument were illustrated and proved by photographs of papyri, ancient and modern maps, sections of the Nile Valley from personal and original surveys, sketches and photographs of natural hills of pyramidal form in Egypt and Nubia, with examples of denudation of horizontal beds elsewhere, the quarries of Turra, the natural strata in the head of the Sphinx and under the Pyramids of Gizeh, and the sides of the Kom el-Kashab, Abu-Roash and the Mokattam. The partially completed façades of Petra were begun at the top. The limestone quarries of the Nile were worked in "stopes" or ledges, in subterranean chambers and passages. Evidence was also furnished that these facts and suggestions had been put before the scientific world in definite form, and had elicited the approval of competent judges. The survey of the Desert to the west of the Pyramids was inserted by Prof. Perrot and M. Chipiez in their history of Egyptian Art (Eng. Ed., 1882). The London *Academy* described with approval how it had been "conceived that the Gizeh plateau was once a range of hills, weathered into fantastic shapes, to which horizontal strata gave an artificial appearance and pyramidal summits," and "the inferior material was cut into blocks, lowered from above and pushed into place to build the Pyramids." The Wadi Reian, eroded to a depth of two hundred feet below the Mediterranean, and the hills in the Wadi Fadhi have been placed upon the map of the British War Office. The Geographical Society of Cairo, 1883, indorsed the surveys of 1882 and 1883 as a new and important contribution to the cartography of the Libyan Desert. The Dutch Academy of Sciences (1884) republished the geographical Papyrus of Boulaq with a map to show that this document had been, hitherto, wrongly interpreted, but the Abbé Amelineau had already demonstrated this at length in the *Revue des Questions Historiques*, (Oct., 1883). The Report of the New York Academy of Sciences (*Critic*, April 5th, 1884), refers more particularly to the proof that "horizontal limestone once filled the Nile Valley to the height of nearly a thousand feet, and several hundred feet above the tops of the Pyramids," and that "the tombs under the Pyramids appear to be older than the structures above," while the granite blocks (from Assouan) and coffer, being too large to have been brought through the entrance and passage, may have been put into the hill before it was reconstructed into a pyramidal pile of rough-hewn stones.

The Society of Civil Engineers at its meeting June 12, 1884, (see the *American Engineer*) agreed that the stones

might have been actually quarried in a hill and lowered into their present position so that the amount of labor would have been exceedingly small in comparison with that required to construct the piles by concentric and successive layers. At the meeting of the British Association for the Adv. of Science in Montreal (Aug. 27, 1884) reported in the Oct. No. of the Proceedings of the Royal Geog. Soc., the accuracy of the ancient historians was shown and the use of technical words explained. The restoration of the South-Western basin (see *Saturday Review*, Jan. 25th; 1883; *The Century*, October, 1884) was advocated. The Ptolemaic maps were justified by the levels run by theodolite and spirit level as well as aneroid barometer, alone or with the aid of Messrs. Ellis, Gasperoni, Petrie and others. Wide fields of archæological research were indicated and a hieroglyphic inscription from Edfou cited as conclusive of the former extent of Lake Mœris, while the complete absence of early reference to the Pyramids confirms the conjecture that they are comparatively modern, and did not exist in the time of Rameses-Sesostris. The reopening of Lake Mœris would greatly facilitate an Alexandria-Cairo-Suez Canal.

It is obvious that unless these facts are contradicted, it is legitimate to infer that the situation of the Pyramids is an important factor in the question of their purpose. The problem of their construction is to find the easiest and most natural method. Why hills at, in or near Lake Mœris should have been revetted, or reconstructed, into square or rectangular masses with sloping sides may never be explained, but, even in that event, a stigma is removed from the history of the human race, and especially from its engineers, by showing that these are not piles of stone, quarried on the right bank of the Nile and transported to the left bank, only to serve as a tumulus above or around the nameless sarcophagus of an unknown personage.

## THE MANCHESTER SHIP CANAL SCHEME.

By H. S. S. SMITH, C. E., Princeton College.

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THE proposition to make Manchester a sea-port is not a new one. Like every great undertaking, it has been preceded by various plans to accomplish the same purpose. Forty years ago Mr. Palmer agitated the question, and since then Mr. Bateman and Mr. Fulton have been earnest in their endeavors to have the idea reach actual achievement. It is, in a certain sense, unfortunate that the present discussion of the subject has thus far been barren of material results, for no one denies that the proposal, if practicable, would be of great benefit to a large and active manufacturing center. But the grounds on which permission has been denied by Parliament are evident and reasonable, and it remains to be seen whether or not the same object can be reached in a way that will not be detrimental to existing interests.

The present agitation of the question took a definite form in June, 1882, when a provisional committee was formed in Manchester and began active operations by appointing Mr. Hamilton Fulton and Mr. E. Leader Williams engineers to prepare reports and estimates of the proposed undertaking. Each of these engineers made a report to Mr. Abernethy, the consulting engineer, the two plans being so radically different that it was impossible to combine them into one. Mr. Fulton's proposal was "to straighten, deepen and widen the Irwell and Mersey between Trafford Bridge, Salford and Liverpool so as to afford a depth of 22 feet at low water of spring tides." As this plan would require a rock-cutting 40 feet deep and 10 miles long, and would place the docks at Manchester 92 feet below the present surface of the ground, the report was not adopted by Mr. Abernethy. The report made by Mr. Williams was essentially different, and was the basis of the proposal that was laid before Parliament. He proposed to excavate a ship canal in the

valleys of the Irwell and Mersey from Manchester to Runcorn, a distance of 21.25 miles. This canal was to have locks, worked by hydraulic power, with steam reserve in case of drought. From Runcorn the channel in the estuary was to be straightened and deepened by dredging and by the erection of training walls. There would thus be two distinct parts to the work, the canal portion from Manchester to Runcorn, and the estuary portion from Runcorn to the deep water just above Liverpool. Mr. Williams made detailed plans and estimates for the former, but it would appear that no estimates were made for the portion of the work below Runcorn.

A bill was drawn and brought before Parliament, but, as the standing orders had not been fully complied with, it was admitted only by special permission, and after considerable debate. The supporters of the bill were the merchants and local boards of Manchester, the chambers of commerce of many places that would be benefited by the works, and the manufacturing interests generally. The opponents were the railway companies having lines between Liverpool and Manchester, the various local boards of Liverpool, and the harbor boards and navigation companies having interests in the river Mersey. That the canal was needed, and would be beneficial to a large volume of trade, was proved beyond doubt. But the lack of definite plans and estimates for the estuary part of the work told heavily against the promoters of the enterprise. The committee of the House of Commons, after a patient and thorough investigation, lasting thirty-seven days, passed all of the bill excepting that portion referring to the work in the estuary, reserving decision on it until full plans and estimates should be laid before them. The Committee of Lords, after a brief and superficial inquiry, decided that it was not expedient to proceed with the subject during that session.

The time intervening between this and the next session of Parliament was spent by the promoters in altering the location and plans, and perfecting the estimates of the canal part, and in designing the plans for the channel in the estuary. When the bill came again before Parliament there were no formal technicalities to contend with, but the opposition produced strong engineering arguments against the scheme. Committees investigated the matter as before, and the result was that the Lords passed the bill, while the Commons Committee refused to do so. It is said that $1,500,000 have already been spent in promoting and opposing the bill. As there is reason to believe that the real cause of the defeat of the bill was the engineering evidence produced by the opposition, it will be interesting to study the circumstances of the case, and see what the conditions really were.

To understand the plans it will first be necessary to give a brief description of the existing waterway from Manchester to the open sea. The city is situated on the Irwell, a small stream having a depth of only four feet under favorable circumstances. Flowing westward from Manchester, it joins the Mersey after a winding course of about 6 miles. The direction and character of the stream remain practically unchanged to Warrington, 15 miles below Manchester. From this place to Runcorn, 6 miles below, the limit of draught is 9 feet. At Runcorn the river meets the estuary, a basin whose shape is that of an irregular crescent, the direction of the general axis changing from nearly westerly at Runcorn to nearly northerly at Dingle Point.

The length of the basin is about 12 miles, and the area is 27.2 square miles. At low water about 20 square miles of sand banks are uncovered, and the channels between have an effective depth of but 12 feet. The banks and channels are subject to continual and rapid change under the action of the tide. The outlet is a channel extending from Dingle Point to Rock Lighthouse, about 5.5 miles in length, and from 0.6 to 1.0 mile in width. This channel is lined with docks on both sides, Liverpool being on the east and Birkenhead on the West; and, although the mid-channel at low water has a depth of 70 feet, the deposition of silt in the dock slips is so steady that constant dredging is necessary to preserve their usefulness. Rock Lighthouse is at the head of Liverpool Bay. The two parts of the shore of the bay are nearly at right angles to one another, the eastern shore inclining slightly west of the direction of the channel from

Dingle Point to Rock Lighthouse, and reaches to Formby Point, while the southern shore extends in a direction a little south of west to Hoylake Lights, near the mouth of the river Dee. From Rock Lighthouse to the open sea the distance is about 11 miles. The whole of the bay is occupied by banks and shoals, about 34 square miles being entirely uncovered at low water. There are two main channels across the bay. The principal one, Crosby Channel, is a continuation of the Mersey from Rock Lighthouse to Crosby Light, and then turns to the north-west and crosses the bar at the Bar Lightship. A less important one is the Rock Channel running westward from Rock Lighthouse along the Southern shore of the bay nearly to Hoylake Lights, and then turning north to the bar. Across the entire seaward face of the bay there is a bar that gives, when in its best condition, a depth of only 12 feet at low water. The banks, channels and bar are constantly changing under the wear of the tides, and, although the changes are not particularly rapid, they are sufficient to demand constant watching on the part of the harbor authorities.

While the character of the bottom and the configuration of the shores render the channels and harbor far from convenient and safe for shipping, the height and violence of the tide add much to the complexity of the situation. The total rise of an ordinary tide is 30 feet. The water, coming from the west, and confined between limits that are continually narrowing, develops a high silt-carrying capacity. In the channel between Rock Lighthouse and Dingle Point the velocity of the tidal current is as high as 5.5 miles an hour. Reaching the broad basin between Dingle Point and Runcorn the velocity and, consequently, the silt-carrying power are much diminished, and a rapid deposition of silt takes place. This action is rendered more complete by the fact that for more than half the length of the estuary high water occurs at the same time, and the surface is consequently level. The surface remains level for 2 hours and 40 minutes, and although it falls 13.5 feet in that time the current is scarcely perceptible. From this condition of things there results a rapid and almost complete deposition of the silt brought in by the flood tide on the higher banks in the basin. As these banks are, in many places, only five feet lower than high-water level, by the time the ebb currents begin to run with any decided velocity they have become completely uncovered, and the silt deposited on them by the flood is above the reach of any erosive action. But the velocity of the water in the low water channel is sufficient to enable it to carry a large amount of silt, and the banks of these channels are being continually undermined and broken down by the wearing action of the water in a way quite similar to that shown in the caving banks of the Mississippi. This action produces constant change in the position of the channels, a change so prominent that monthly surveys of the estuary are necessary in the interests of navigation, and the buoying of the channels is a matter of constant care. Although the changes are constant the results are remarkably uniform, the amount deposited by high water and the amount excavated by the low-water currents being just about equal day after day and year after year. The action of the tide in Liverpool Bay is to change the banks and channels to some extent, but not rapidly, while its principal effect is in keeping the bar scoured down to a depth that permits navigation. The bar is the most troublesome part of the entrance to the Mersey, and while the depth at low water is seldom more than 12 feet, and thus prevents continuous passages by ocean steamers, it is considered by the harbor authorities at Liverpool as better than none, and must not be meddled with.

The plans for the canal from Runcorn to Manchester showed an engineering project of large dimensions, but free from any special difficulty. In section, the canal would have a breadth of 120 feet at the bottom, side slopes of 1.5 to 1 in earth, but varied in rock, and a depth of 26 feet. The locks would all be similar in plan, but with different lifts. The plan shows three separate basins side by side, 550 by 60 feet, 300 by 40 feet, and 100 by 20 feet, respectively. Sluices were to be built in connection with each set of locks to pass the overflow and storm waters into the lower levels.

Starting from the Mersey at Astmoor

Marsh, about a mile above Runcorn, the canal would keep a straight westerly course for 9.75 miles. At 0.75 miles from Astmoor Marsh is placed the first set of locks, providing a lift of 17 feet at low tide, while high water would flow 5 feet above the intended water level. It was intended that this five feet of water should be used to scour the canal and the channel in the estuary at low water. At 4.5 miles, near Warrington, the London and Northwestern, and the Birkenhead, Lancashire and Cheshire Railways are met. In order that these might pass at a sufficient height it would be necessary to raise the grades at crossing some 43 feet, and the approaches would be about a mile long on each side and have gradients of 1 in 132. To accommodate the trade at Warrington, it was determined to build there a dock 20 acres in extent, with lines of track running from it to the railways. The dock would be connected with the Mersey by a small lock suitable for river craft. At 7 miles the Warrington and Stockport branch of the London and Northwestern Railway would be passed, the plan of passing being the same as for all the other railways. At 7.25 miles there would be the Latchford locks, with a lift of 15.5 feet. The canal would then follow the valley, but would be independent of the river, crossing the bed of the river several times. Below the limit of tidal flow at Woolton Weir the river would be diverted, but above that point the proposition was to turn all the water of the Irwell and Mersey into the canal, and to fill the bed of the stream thus abandoned with earth from the canal cuttings. At 13.25 miles the canal would pass under the Liverpool and Stockport Railway, and at 14.5 miles, under the Liverpool and Manchester Railway. In each of these cases it would be necessary to raise the grades 40 feet, and to make the approaches in the same manner as for the other lines. At 14.75 miles there would be the third set of locks, the Irlam locks, having the same plan and sluices as the others, but with a lift of 13.5 feet. The work just below these locks would be heavy, but it would seem better to have the railways cross the lower level. Continuing to follow the valley with gentle curves the canal, at 17.25 miles, would reach the last set of locks at Barton. These would be the same as those at Irlam. At 18.1 miles the canal would pass under the Barton aqueduct of the Bridgewater Canal, built by Brindley in 1760. It would be necessary to make some arrangements to get the ships past this, as the headway would be insufficient. It was proposed to build a new aqueduct, of which a part should be an iron trough balanced on a central pier and fitted with watertight gates, so that it could be swung around in the manner of a drawbridge. From this place to Manchester the canal would follow the valley of the Irwell, and finally reach the proposed site of the docks, 21.25 miles from the beginning of this portion of the work. It was proposed to take the Manchester Racecourse grounds for the docks of the ship canal. The surface would be 6 to 8 feet above the water surface, and by excavating a water space of 70 acres to the depth of 26 feet, it was expected to give accommodation to 1,260,000 tons of shipping per year. By widening and deepening the Irwell above the docks this could be increased to a capacity of 1,800,000 tons with the additional advantage of improving the connection between the ship canal and the smaller canals centering at Manchester. It was estimated by the engineers that this portion of the work would cost $25,800,000, and could be completed in four years.

The construction of the works in the estuary presented a problem containing many uncertainties. The general plan was to construct training walls from the end of the canal to Garston Docks, a point about 4 miles above Dingle Point, and thus cause the low water channel to keep a definite position. This channel would gradually increase from 300 feet to 1,000 feet in breadth, and would be dredged to a depth of 26 feet at low water. It was found that there was good foundation, either of rock or gravel, at a reasonable depth on which these walls could be built. Materials for the walls would be easily obtained from the rock cuttings on the canal. The difficulty lay, not in the construction, but in the probable effect of the proposed training walls on the tidal flow in the estuary, on the deposition of silt, and on the tidal capacity of the basin. It was proposed by the promoters of the scheme, and the proposition was sanctioned by the surveyor

of the port, to make the walls of such a height that they would "never remain wholly uncovered during the whole of any neap tide." It was argued that by so doing the tidal capacity of the basin would not be decreased, but, on the contrary, would be increased, by the deepening of the channel that would result from the constant scouring. It was argued that the increased velocity that would result would increase the silt-carrying power, and that the proposed improvements would not only serve the purpose for which they were made, but would result in a permanent improvement of the channel from Dingle Point to and across the bar. While this reasoning seemed very just on the face of it, it was proved to be false reasoning on insufficient grounds, and it was here that the opposition made a successful stand. The Mersey Dock and Harbor Board, opposed to the construction of the canal because the trade at the Liverpool docks would be much decreased thereby, engaged Mr. J. B. Eads to investigate the subject of the tides in the estuary and bay, and to report on the probable effect of the construction of the proposed training walls on the tidal capacity of the estuary and on the channels in the bay. The results of his investigations on the tides, and the manner in which they carry and deposit sediment and keep the capacity of the basin uniform have been already given. Bearing the facts in mind, it will be comparatively easy to trace out the sequence of results that would follow from the construction of such walls as were proposed. The deposition of silt on the shoals in the estuary would, at first, be as before; but the wearing action of the low-water currents on their banks would be stopped by the training walls, and there would result an inequality between the gain and loss of silt in the shoals with a balance in favor of the increase. This would soon raise the height of the shoals nearly to the level of high tide, and the capacity of the basin would be decreased by an amount nearly equal to this, for the increase of capacity coming from the increase of depth of the channel would be small in comparison with the volume occupied by flood tide. The tidal capacity of the basin being thus decreased by the gradual deposition of silt on the shoals, the volume of water transported as tidal flow would be correspondingly lessened, and the velocity of the tide would be reduced. This reduction in velocity means a still greater reduction in silt-carrying capacity, because this latter varies as the square of the velocity. The reduction of volume, velocity and silt-carrying capacity would be effective, not only in the estuary between Dingle Point and Runcorn, but also in the channel between Dingle Point and Rock Lighthouse, and over the whole extent of Liverpool Bay between the lighthouse and the bar. The result would evidently be that the depth of the channel opposite Liverpool would be lessened by silting, and that even the present shallow depth of water on the bar would be decreased. These facts and their logical results were placed before the Parliamentary committees in a clear and forcible manner, and it is not strange that they refused to pass the bill.

It has been admitted on all sides that the proposed undertaking was one that would be of very great benefit to a large and active manufacturing center, and because one plan has been proved to be not feasible is no reason for thinking that the object in view cannot be attained. There are still at least three ways of providing a deep water channel from Manchester to the sea. One of these would, at the same time, greatly benefit the communication between Liverpool and the sea, while the other two would have no influence at all on the existing waterways below Dingle Point.

The expedient suggested by Mr. Eads, in answer to questions put to him when before the committees, was to construct a ship canal similar to the one proposed, but extending all the way from Manchester to the sea. That is, instead of entering the estuary of the Mersey at Runcorn it would pass to the south, skirt the Cheshire shore of the estuary, and enter tidal waters somewhere between Rock Lighthouse and the mouth of the river Dee. Although no detailed estimate of this work has been made, it would appear that there would be no great difficulty in the way of such a plan.

While it must be acknowledged that a close acquaintance with the hydrography of the place is necessary to warrant the elaboration of a scheme for realizing the

desired end, a close scrutiny of the many facts that have been elicited by the agitation of the question fails to show why either of the following schemes would be impracticable when viewed from an engineering standpoint. Each of them would, however, seriously and completely interfere with the riparian rights along nearly the whole of the present shore of the estuary.

The first one to be mentioned, the less expensive one of the two, and the one that would have no prominent influence on the channels and bar of the bay, is this: Starting from the proposed terminus of the canal proper at Runcorn, construct two training walls whose tops should ultimately be above high water of spring tides, and place them at such a distance apart that at any place the area of the cross section between them occupied by the water that comes in at flood tide would be equal to the present area occupied by the flood on the same cross section; or, rather, so proportion them that the total volume between them occupied by the water of flood tide would be equal to the present tidal capacity of the estuary. Thus, opposite Ellesmere Docks the low-water channel has a breadth of 0.4 miles, while the remaining 3.1 miles are covered by shoals at low water. The breadth of an equivalent channel would be about 2.1 miles. Or, if these training walls were to be a uniform distance apart, this distance would be about 1.3 mile, in order to furnish the same tidal capacity as at present. At Dingle Point, or a little above, these walls should be made to join the shores on either side. Since the depth and uniformity of a channel have a great influence on the velocity and the consequent silt-carrying capacity of a tidal current, it would seem that the condition of the channels below Dingle Point would be improved by such a change in the estuary.

The second scheme is of much greater magnitude. It would make an unimpeded deep-water channel all the way from Runcorn to the open sea, by the erection of high-tide training walls from Runcorn to Dingle Point, and from Rock Lighthouse to deep water, leaving the channel between Liverpool and Birkenhead untouched. While this would diminish the tidal capacity of the bay and of the estuary, it would keep all of the tidal action within definite boundaries, so that there would be no opportunity for the formation of shoals. There would, however, be the probability of decided difficulty in the matter of the deposition of silt at and near the mouth of the channel. There is no large body of water flowing seaward to carry away the silt, as in the case of the Mississippi. It would be exceedingly difficult to predict what the depositing action would be, as it appears that some kind of a geological change is in progress in connection with the complicated tidal action.

With either of these schemes there would be the difficulty of leaving the present docks and water fronts along the shores of the estuary far removed from any navigable channel, and the formation between 10 and 20 square miles of new land between the proposed channel and the present shores. Whether these would be sufficient to prevent the carrying out of the plan is a question that must be decided on the spot. In any case, however, the formation of a deep-water channel from Manchester to the sea is not an impossibility, and will probably be an accomplished undertaking before the end of the century.

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FROM a paper read before the Royal Institution by Professor J. W. Judd, it appears that the Krakatoa cataclysm destroyed over 35,000 people, but as a volcanic outburst it was comparatively small to that of Tomboro in 1815. The Krakatoa was, however, more violent for the few hours it lasted than the Tomboro during its thirty days. The size of Krakatoa was formerly 33½ square kilometers; of that 23 square kilometers have subsided, and 10½ square kilometers remain extant. But on the south and southwest side the island has been increased by a large ring of volcanic products, so that the size of New Krakatoa is now, according to the survey, 15¼ square kilometers. The size of Long Island was formerly 2.9 and is now 3.2 square kilometers. Verlaten Island has become much larger; it was formerly 3.7 and is now 11.8 square kilometers in size. Of the Poolsche Hoedje nothing remains. In the place where the fallen part of Krakatoa once stood there is now everywhere deep sea, generally 200, in some places even more than 300, meters deep. It is remarkable that in the midst of this deep sea a rock has remained, which rises about 5 meters above its surface. Close to this rock, which is certainly not larger than 10 meters square, the sea is more than 200 meters deep. It is like a gigantic club, which Krakatoa lifts defiantly out of the sea.

# ON THE PRESERVATION OF IRON BRIDGES.

By E. PASCHEN.

From Abstracts of the Institution of Civil Engineers.

THE author urges the growing necessity for the general adoption of some system, whereby the condition of existing iron bridges may be ascertained and recorded, and periodical inspections of all such structures be made in the future.

As regards the iron bridges erected in Germany, those upon the earliest constructed lines of railway, although not intended to carry the heavy class of locomotive now in use, were designed with such an ample margin of strength and constructed in so careful a manner as to be equal to the increased stress produced by the present type of engine; but with the progress of railway construction, investigation led to more familiarity with the direction and amount of strains upon bridge structure, and there ensued a desire, which seems to have become general, to economize the amount of metal to the utmost, basing the calculations upon the then existing conditions, and disregarding the possibility of the introduction of a heavier class of locomotive; so that, at the present time in many bridges, the metal, at the transit of every train, is subjected to strains in excess of that which is assumed to be permissible.

This applies more to small than large spans, as the amount of increased load, due to the use of heavier engines, is proportionally greater in the case of the former than of the latter. With the increase in the number and magnitude of bridges erected, a tendency to deterioration in the character of the work and material employed ensued.

The author mentions the failure in some instances of the hinge ("Pendel") bed-plate, and advocates the use of the usual expansion roller frame only, and, after enumerating the evils arising from various causes, such as the removal of the overhead transverse ties in the case of deep girders (causing lateral distortion), insufficient riveting at the intersection of lattice bars, inattention to condition of paint, and the non-provision of a sufficient thickness of timber between the rail and the ironwork of the structure, points out the necessity for the employment of competent inspectors during the progress of the work, both at the place of manufacture and erection.

Reference is made to the Society of Architects at Berlin, which has directed its attention to the question, and proposes that the railway companies generally should institute a system of periodical inspections and reports as to the condition of their various iron bridges, and recommend that the observations should be divided into two classes, the first (general) to be made in respect of every bridge, and the second in special instances only.

"The general observations (to be made every five years) to include—

"1. Measurement of permanent deflection.

"2. Measurement of deflection caused by loading (at rest).

"3. Enumeration of those portions of the structure and rivets which may have already been renewed.

"4. Careful examination of plates at junctions of bracing with booms, &c.

"5. Careful examination of paint and those places affected by rust.

"The special observations (to be made annually) to include—

"6. Deflection of the lower flange under a moving load.

"7. Distance apart of the top and bottom flanges.

"8. Length of the diagonals.

"9. Lateral distortion and vibration at the center of the girders.

"All observations upon the structure when repeated, to be, if possible, made by the same inspector."

In modification of the above the author suggests that the result of observations made by mere inspection should be kept separate from those obtained by loading, as the former could be made at any time at comparatively slight expense, and the most important of the defects discovered, whereas the latter would necessitate the presence of a sufficient number of en-

gines of the heaviest class, and for the time being, stop all traffic; he therefore proposes that subordinates should be first carefully instructed under the supervision of the chief inspector, and that afterwards it should be their duty frequently to examine the structures, a formal report from personal observation being made by him once in two years, and that the load-test should be employed only once in ten instead of five years.

The special observations, it is suggested, should include the effect of temperature upon the length of the girders, the amount of movement in the roller bed-plate with trains moving in both directions, the comparative distances apart of the web-verticals, measured near the top and bottom flanges when the girder is loaded, and the lateral deflection caused by wind-pressure under the conditions of a loaded and unloaded girder.

The author recommends that a book should be kept for the entry of the inspectors' report, the information being under the following headings, viz., name, short description, and, where possible, the calculation of the strains, and a general sketch with details of the most important parts; weights of iron in the construction, total weight of superstructure; details as regards the history of the construction, name of maker, &c.; character of the materials, and results of experiments as to strength, amount of deflection under moving and fixed load, &c.

An example is given of an entry in the Bridge-Book, with a sketch referring to the Werda Bridge, a double-line structure of six 67-feet spans.

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# THE EFFICIENCY OF FLUID IN VAPOR ENGINES.

By H. L. GANTT, A. B., M. E., and D. H. MAURY, Jr., M. E.

Contributed to Van Nostrand's Engineering Magazine.

I. The determination of the efficiency of fluid of different vapors was suggested by Prof. R. H. Thurston to the writers as a subject demanding investigation.*

This suggestion was the more gladly accepted as the writers had desired to investigate, and if possible, to make a practical test of, a vapor engine, which was at that time awakening some interest in engineering circles in New York City and elsewhere. Failing to obtain permission to test the engine in question, the writers were compelled to confine themselves to a purely theoretical discussion of the subject.

2. Rankine, Clausius and others have proved that the amount of heat transformed into work does not depend upon the fluid which is the conveyor of that heat, but simply upon the limits of temperature between which the fluid is worked. It follows that, theoretically, all fluids are equally efficient in transforming heat into work; it does not follow, however, that all fluids are equally valuable as the working fluid of an engine, for there are other considerations beside efficiency to be taken into account in making choice of a working fluid. We have set ourselves the task of choosing the best working fluid from the following liquids: water, alcohol, ether, bisulphide of carbon and chloroform.

## Case I.

3. This section is devoted to a discussion of Carnot's cycle, first in general, and then as applied to the vapors in question, with the object of showing that, while the efficiency of fluid is the same in each case, that of the engine may be different, and in general will be, since its efficiency will be less as the size of engine required to produce a given power is larger.

4. Carnot's cycle consists of an isothermal expansion, an adiabatic expansion, an isothermal compression, and an adiabatic compression up to the original temperature.

We shall suppose a certain amount of heat, $L_1$, to be worked in the cycle of Carnot, between the limits of temperature $t_1$ and $t_2$, by any fluid, and then by each of the fluids in question, and shall show that, while neither the work of expansion nor

* The writers take this occasion to express their gratitude to Professor Thurston for his great kindness in placing at their disposal his valuable library, and for the many other favors shown them during the progress of their work.

that of compression in any case is equal to the corresponding quantity in any other case, their difference, the effective work, is equal in all cases.

We suppose our fluid to be at the temperature $t_1$, and that we have just so much of it as will be evaporated by the heat $L_1$. The evaporation accompanies the isothermal expansion represented by AB, Plate I., Fig. 1. The adiabatic expansion BC, then takes place until the temperature falls to $t_2$; the isothermal compression is shown by CD and the adiabatic compression by DA.

5. Rankine gives as the formula for the rates of expansion necessary to reduce the temperature of steam from $t_1$ to $t_2$ *

$$r=\frac{\tau_2}{L_2}\left(JD_1 \log_{.e} \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right).$$

$\tau_1$=absolute initial temperature on the Fahrenheit scale.

$\tau_2$=absolute final temperature on the Fahrenheit scale.

$L_1$=latent heat of evaporation of a cu. ft. of vapor at temperature $t_1$, in foot pounds.

$L_2$=latent heat of evaporation of a cu. ft. of vapor at temperature $t_2$.

$D_1$=weight in lbs. of cu. ft. of vapor at temperature $t_1$.

J=mechanical equivalent of heat in foot pounds.

This formula may be made applicable to all vapors by the introduction of K, the specific heat of the liquid, as follows.

$$r=\frac{\tau_2}{L_2}\left(JD_1 K \log_{.e} \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right) \quad . \quad (1)$$

The formula for the work done per stroke, in a steam engine, by a unit volume of vapor at temperature $\tau$, as given by Rankine † is

$$\text{Work}=JD_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+r(p_2-p_3),$$

which may be made applicable to all vapors by the introduction of the specific heat K of the liquid. It then becomes

$$\text{Work}=JKD_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+r(p_2-p_3) \quad . \quad . \quad (2)$$

The pressures $p_2$ and $p_3$ are the tensions of the vapor at the temperatures $t_2$ and $t_3$ in pounds on the square foot; $t_3$ being the temperature of the condenser, $p_3$ is the back pressure.

6. Equation (2) may be illustrated by the diagram, Plate I., Fig. 1. The ordinates represent pressures and the abscissas represent volumes. AO=$p_1$ the initial pressure. CG=$p_2$, the final pressure. HG and KO represent $p_3$, the back pressure. Equation (2) is an expression for the work represented by ABCHK. If the final and back pressures become equal, equation (2) becomes

$$W=JKD_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1 \quad . \quad . \quad (3)$$

and the diagram representing the work is ABCE.

If an amount of heat, $L_1$, is added to a fluid at the temperature $\tau_1$, and then worked in the cycle of Carnot between the temperatures $\tau_1$ and $\tau_2$ the amount of heat changed into work is $\frac{\tau_1-\tau_2}{\tau_1}L_1$, as shown by Rankine, Clausius, and other writers. From this it follows that the work represented by ABCD is equal to $\frac{\tau_1-\tau_2}{\tau_1}L_1$, and therefore the work of adiabatic compression in the cycle of Carnot is

$$JKD_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau_2}\right)\right\}$$

The total work of compression $v^2$, being the volume at the end of adiabatic expansion is

$$p_2v_2+JKD_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau_2}\right)\right\}.$$

If the amount of vapor produced by the heat $L_1$ is not a unit volume, but is represented by $v_1$, the work of expansion in Carnot's cycle becomes

$$W=JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log_{.e}\frac{\tau_1}{\tau^2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+v_2p_2, \quad . \quad (4)$$

* Steam Engine, p. 388.
† Steam Engine, p. 388.

Plate I.

Pressures.

Plate I.

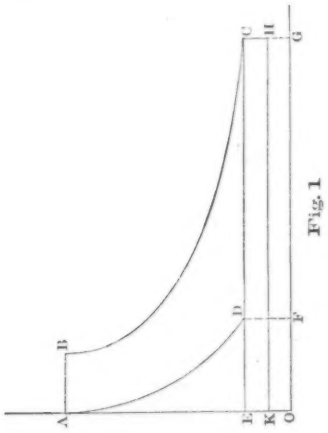



Fig. 1

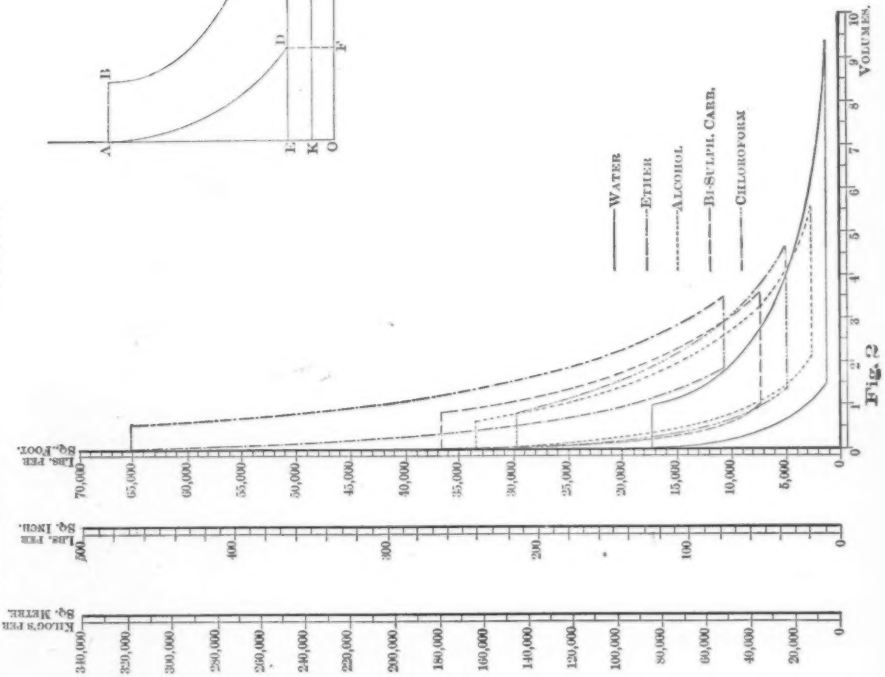



Fig. 2

which is represented by ABCGO; the total work of compression is

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log.\epsilon\frac{\tau_1}{\tau_2}\right)\right\}+v_2p_2,$$

$v_2p_2$ being represented by CGOE, and

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log.\epsilon\frac{\tau_1}{\tau_2}\right)\right\}, \text{ by ADE.}$$

The effective work is $\frac{\tau_1-\tau_2}{\tau_1}L_1$.

7. As all the data available for the solution of this and the following cases are found in French and German works, and are consequently expressed in the metric system, we have adopted that system. The principal data and results however, are reduced to British units, and are given in both British and metric systems in a table at the end.

It is necessary to find the quantities required for substitution in equations (1) and (3), which data are:

$J=424$ kilogrammeters.

$\tau_1$ and $\tau_2$, initial and final absolute temperatures on the Centigrade scale.

$L_1$ and $L_2$, latent heats of evaporation, in kilogrammeters, of one cu. me-

ter of saturated vapor at temperatures $\tau_1$ and $\tau_2$ respectively.

$D_1$ and $D_2$ = weights in kilograms of one cubic meter of saturated vapor at temperatures $\tau_1$ and $\tau_2$ respectively.

$p_1$ and $p_2$ = tensions, in kilograms on the square meter, of the vapors at the temperatures $\tau_1$ and $\tau_2$.

K = mean specific heat of the liquid between the temperatures $\tau_1$ and $\tau_2$.

8. The initial and final temperatures chosen are

$$t_1 = 172°\text{ C. and } t_2 = 90°\text{ C.}, \quad \text{or}$$
$$T_1 = 445°\text{ C. and } T_2 = 363°\text{C.}$$

The pressures corresponding to these temperatures were taken either directly, or by interpolation, from tables given in Vol. II. of Regnault's "*Experiences*" whenever it was possible. When, however, owing to the limited range of temperatures given in these tables, this was impossible, the following formula given by Wüllner, "*Lehre von der Warme*," p. 617, was resorted to—

$$\log. S = a + ba^t + c\beta^t \quad . \quad . \quad . \quad (5)$$

in which $a$, $b$, $c$, $\alpha$ and $\beta$ are constants, $t$ the temperature on the Centigrade scale, and S the pressure in millimeters of mercury.

For greater convenience of calculation Wüllner puts the constants in the following form:

| | $a$ | Sign of $ba^t$ | log. $ba^t$ |
|---|---|---|---|
| Alcohol.. | 5.4562028 | − | .6390301 − .0029143 $t$ |
| Ether.... | 5.0286298 | − | .4414317 − .0031223 $t$ |
| Bi-sulph. of carb.. | 5.4011662 | − | .4918860 − .0022372 $t$ |
| Chlorof'm | 5.2253893 | − | .5219943 − .0025856 $t$ |

| | Sign of $c\beta^t$ | log. $c\beta^t$ |
|---|---|---|
| Alcohol.... | + | .5050675 − 3 − .0590515$t$ |
| Ether..... | + | .6512970 − 4 + .0145775$t$ |
| Bi-sulph. of carb..... | − | .2799632 − 1 − .0119062$t$ |
| Chloroform | − | .0888717 − 1 − .0131824$t$ |

The tensions for vapor of water were taken from a table of Regnault's results given by Wüllner on p. 610 of "*Lehre von der Warme.*"

The tensions found as just explained are

| | $S_1$. | $p_1$. |
|---|---|---|
| Water..... | 6,214 6 | 84,518 |
| Alcohol ..... | 12,103 | 164,600 |
| Ether ..... | 23,458 | 318,970 |
| Bi-sulph. of carb..... | 13,179 | 179,230 |
| Chloroform..... | 10,715 | 145,720 |

$S_1$ representing the tensions in millimeters of mercury, and $p_1$ the same tensions in kilograms on the square meter.

9. We now wish to find D, the weight in kilograms of a cubic meter of saturated vapor at the temperature $t$.

On page 668, in his "*Lehre von der Warme*," Wüllner gives, as the result of the work of Herwig on the density of saturated vapors, the formula

$$V_1 = \frac{pv}{p_1 \times .0595\sqrt{a+t}} \quad . \quad . \quad . \quad (6)$$

in which $V_1$ = volume in cubic meters of one kilogram of saturated vapor at the absolute temperature $a+t$; $p_1$ = tension of the vapor in millimeters of mercury at that temperature; while $p$ and $v$ represent the pressure and volume that the vapor would have at that temperature if it obeyed Marriott's law. If we suppose the vapor far enough removed from the point of saturation to act as a perfect gas, the following law holds good:—

$$pv = p_0 v_0 (1 + at) = a p_0 V_0 (a + t),$$

$a+t$ being the absolute temperature corresponding to the temperature $t$, and $V_0$ the volume of a unit weight of vapor under pressure $p_0$ at temperature O° Centigrade. If we let $V_0'$ represent the volume of a unit weight of air under the same pressure and at the same temperature, the density of the vapor referred to air is

$$\delta = \frac{V_0'}{V_0} \therefore V_0 = \frac{V_0'}{\delta}.$$

Making this substitution, the product $pv$ becomes

$$pv = \frac{a p_0 V_0' (a+t)}{\delta} \quad . \quad . \quad . \quad (7)$$

For air, if $p_0 = 760$ m. m., $V_0' = .77339$ cu. meters. For perfect gases $a = .00366$. Substituting in (7) we have

$$pv=\frac{.00366\times760\times.77339\times(a+t)}{\delta},$$

which being substituted in (6) gives

$$V_1=\frac{.00366\times760\times.77339\times\sqrt{a+t}}{p_1\delta\times.0595}$$

Reducing we get

$$V_1=\frac{36.2\sqrt{a+t}}{p_1\delta} \quad . \quad . \quad . \quad . \quad (8)$$

in which $p_1$ is the tension of the saturated vapor at temperature $t_1$, and $V_1$ is the volume in cubic meters occupied by one kilogram of vapor at the same temperature.

It follows that the weight $D_1$ in kilograms of a cubic meter of saturated vapor is

$$D_1=\frac{1}{V_1}=\frac{p_1\delta}{36.2\sqrt{a+t}} \quad . \quad . \quad . \quad (9)$$

The densities, $\delta$, of the several vapors, referred to that of air, are given by Clausius in his "Mechanical Theory of Heat," page 59* and are

| | $\delta$. |
|---|---|
| Water | .6219 |
| Alcohol | 1.5819 |
| Ether | 2.5573 |
| Bi-sulph. of carb. | 2.6258 |
| Chloroform | 4.1244 |

Substituting in equation (9) we find $D_1$ and $D_2$ corresponding to the temperatures $t_1=172°$ C. and $t_2=90°$ C.

| | $D_1$. | $D_2$. |
|---|---|---|
| Water | 5.07 | .467 |
| Alcohol | 25.18 | 2.74 |
| Ether | 78.66 | 14.47 |
| Bi-sulph. of carb. | 45.37 | 9.98 |
| Chloroform | 57.84 | 11.13 |

10. The latent heats, $L_1$ and $L_2$, of evaporation per cubic meter of saturated vapor in kilogrammeters at temperatures $t_1$ and $t_2$ are now to be found.

On page 640 of "*Lehre von der Warme*," Wüllner gives the formula

$$\lambda=a+bt+ct^2 \quad . \quad . \quad . \quad . \quad (10)$$

for the latent heat of evaporation per kilogram at temperature $t$.

The constants for ether, bi-sulphide of carbon and chloroform are

| | $a$. | $b$. | $c$. |
|---|---|---|---|
| Ether | 94 | −.07901 | −.0008514 |
| Bi-sulph. of carb. | 90 | −.08922 | −.0004938 |
| Chloroform | 67 | −.09485 | −.0000507 |

For alcohol, a table of latent heats for every ten degrees up to 150° C. is given; and for water a similar table up to 194.8° C. (See p. 635 "*L. v. d. W.*")

From formula (10), in which the latent heats are given in calories, and from the tables we get the results:

| | $\lambda_1$. | $\lambda_2$. |
|---|---|---|
| Water | 483 | 542 |
| Alcohol | 159 | 206 |
| Ether | 55.2 | 80 |
| Bi-sulph. of carb. | 60.1 | 78 |
| Chloroform | 49.2 | 58.1 |

By multiplying these quantities by Joule's equivalent, 424 k. g. m., and the products by $D_1$ and $D_2$ respectively, we we get $L_1$ and $L_2$.

| | $L_1$. | $L_2$. |
|---|---|---|
| Water | 1,038,300 | 107,300 |
| Alcohol | 1,697,500 | 239,400 |
| Ether | 1,841,000 | 482,800 |
| Bi-sulph. of carb. | 1,156,100 | 330,200 |
| Chloroform | 1,206,600 | 274,200 |

11. To find the mean specific heat K between $t_1$ and $t_2$, we take the average of the specific heats at those temperatures.

On page 485, "*L. v. d. W.*" is given the formula

$$K_t=A+2Bt+3Ct^2 \quad . \quad . \quad . \quad . \quad (11)$$

for the specific heat at the temperature $t$. The specific heat of water is unity; the values of the constants for the other vapors are

| | A. | B. | C. |
|---|---|---|---|
| Alcohol | .54754 | .0011218 | .000002206 |
| Ether | .52901 | .0002958 | 0 |
| Bi-sulph. of carb. | .23523 | .0000815 | 0 |
| Chloroform | .23235 | .0000507 | 0 |

The mean specific heats between the temperatures 172° and 90° C. found as just explained are:

* Browne's Translation, London, 1879.

| | K. |
|---|---|
| Water | 1 |
| Alcohol | .966 |
| Ether | .607 |
| Bi-sulph. of carb | .257 |
| Chloroform | .246 |

12. Having found the data necessary for substitution in equation (1), we may find the ratios of expansion. They are

| | |
|---|---|
| Water | $r=9.37$ |
| Alcohol | $r=8.97$ |
| Ether | $r=6.11$ |
| Bi-sulph. of carb | $r=3.96$ |
| Chloroform | $r=5.22$ |

We may now discuss the action of each of the five vapors in working 1038300 k. g. m. of heat between the temperatures $t_1$ and $t_2$.

The total work of expansion is given by formula (4), §6, and the work of compression by the next formula. All the quantities required for substitution in those formulas are known except $v_1$ and $v_2$; but $v_2=rv_1$; therefore we have only to find $v_1$. The amount of heat required to evaporate one cubic meter of vapor at temperature $t_1$ being given in §10, we may find the volume of each vapor generated by 1,038,300 k. g. m. by dividing 1,038,300 by the value of $L_1$ in §10.

$$v_1=\frac{1{,}038{,}300}{L_1} \quad . \quad . \quad . \quad . \quad (12)$$

| | $v_1$. |
|---|---|
| Water | 1 |
| Alcohol | .6116 |
| Ether | .5640 |
| Bi-sulph. of carb | .8980 |
| Chloroform | .8615 |

The amount of fluid used is $v_1D_1$ kilogs. Then we have (§6) Work of expansion=

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log.\epsilon\frac{\tau_1}{\tau_2}\right)\right\}+\\ +\frac{\tau_1-\tau_2}{\tau_1}L_1+v_2p_2$$

Work of compression=

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log.\epsilon\frac{\tau_1}{\tau_2}\right)\right\}+v_2p_2$$

Effective work=

$$\frac{\tau_1-\tau_2}{\tau_1}L_1$$

Substituting, we have

| | Work of Expansion. | Work of Compression |
|---|---|---|
| Water | 274,767 | 83,408 |
| Alcohol | 331,322 | 139,863 |
| Ether | 466,740 | 275,381 |
| Bi-sulph. of carb | 354,120 | 162,761 |
| Chloroform | 347,474 | 156,115 |

| | Effect've Work. | Heat Used. | Efficiency. |
|---|---|---|---|
| Water | 191,359 | 1,038,300 | 18.43 % |
| Alcohol | 191,359 | 1,038,300 | 18.43 % |
| Ether | 191,359 | 1,638,300 | 18.43 % |
| Bi-sulph. of carb. | 191,359 | 1,038,300 | 18 43 % |
| Chloroform | 191,359 | 1,038,300 | 18.43 % |

13. In the preceding, we have shown how the work of expansion and that of compression may vary greatly and still leave the effective work constant.

To show more clearly the action of the various vapors working in this cycle, we shall draw a diagram of Carnot's cycle for each case. To do this, it is necessary to find at least two more points in the curve of expansion, and the point at which adiabatic compression begins.

To find the points in the curve of expansion, we assume two temperatures, $t_4$ and $t_5$ between $t_1$ and $t_2$, and find the corresponding volumes and pressures.

If we represent by $r_4$ and $r_5$ the ratios of expansion corresponding to the absolute temperatures $t_4$ and $t_5$, formula (1) for the ratio of expansion becomes

$$r_4=\frac{\tau_4}{L_4}\left(JKD_1\log.\ \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right)$$

in which $L_4$ and $L_5$ have their original signification. As $L_1=D\times J\times\lambda$, we may make this formula more convenient in use by substituting for $L_1$ and $L_4$ their values. The formula then becomes

$$r_4=\frac{\tau_4}{\lambda_4D_4}\left(KD_1\log.\epsilon\frac{\tau_1}{\tau_4}+\frac{\lambda_1D_1}{\tau_1}\right) \quad (13)$$

In order to find $r_4$ and $r_5$ we need $\lambda_4$, $\lambda_5$, $D_4$, $D_5$, K, $\tau_4$, and $\tau_5$; and to find $D_4$ $D_5$ we need $p_4$ and $p_5$.

$\tau_4$ and $\tau_5$ were taken respectively as 418° and 393° C.

K is the same as before.

$\lambda$ is found as before in § 10, D as in § 9, $p$ as in § 8, $p$ being identical with $p_1$ of that article.

These quantities are

| | $p_4$. m. m. | $p_5$. m. m. | $\lambda_4$. | $\lambda_5$. | $D_4$. | $D_5$. | K. | $D_1$. |
|---|---|---|---|---|---|---|---|---|
| Water | 3,125 | 1,491 | 504.7 | 522.6 | 2.63 | 1.29 | 1 | 5.07 |
| Alcohol | 6,485 | 3,232 | 173.1 | 186.8 | 13.87 | 7.16 | .966 | 25.18 |
| Ether | 12,957 | 7,719 | 64.6 | 72.3 | 44.82 | 27.50 | .607 | 78.66 |
| Bi-sulph. of carb | 8,237 | 5,149 | 66.7 | 72.2 | 29.26 | 18.90 | .237 | 45.37 |
| Chloroform | 6,618 | 3,926 | 52.2 | 54.9 | 36.85 | 22.50 | .246 | 57.84 |

Substituting these values we get $r_4$ and $r_5$ the following:

| | $r_4$. | $v_4 = r_4 v_1$. | $r_5$. | $v_5 = r_5 v_1$. |
|---|---|---|---|---|
| Water | 1.83 | 1.83 | 3.51 | 3.51 |
| Alcohol | 1.83 | 1.12 | 3.54 | 2.17 |
| Ether | 1.85 | 1.04 | 3.11 | 1.75 |
| Bi-sulph. of carb | 1.47 | 1.32 | 2.18 | 1.95 |
| Chloroform | 1.58 | 1.36 | 2.60 | 2.24 |

14. It is now necessary to find the point at which adiabatic compression begins. This is done as follows:—At the point D, at which adiabatic compression begins, the mixture of liquid and vapor has the pressure $p_2$ and volume $v_6$. This mixture is then made by compression to assume a volume, 0*, under pressure $p_1$ and at temperature $t_1$, when it becomes reduced entirely to the liquid state. If the fluid now expand adiabatically until it takes the volume $v_6 = ED$ under pressure $p_2$, it will perform the work represented by ADFOA, which may be divided into two parts,

$$EDFO = p_2 v_6, \text{ and } ADE = JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left( 1 + \log_e \frac{\tau_1}{\tau_2} \right) \right\}$$

We have assumed, for convenience of illustration, that the fluid is expanding instead of being compressed. This we may do without error, as the operations of expansion are exactly those of compression reversed.

At the point A, Plate I., Fig. 1, we have $D_1 v_1$ kilograms of liquid at temperature $t_1$, at the point D the same weight of liquid and vapor is under pressure $p_2$ at temperature $t_2$ and occupies the volume $v_6$. Since this expansion is adiabatic, the difference between the sensible heats existing at A and D has been entirely converted, either into work, or into latent heat of evaporation. This amount of heat is

$$H = D_1 \times v_1 \times K \times (t_1 - t_2) \times 424$$

expressed in kilogrammeters.

The work done during expansion is

$$ADFOE = JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left( 1 + \log_e \frac{\tau_1}{\tau_2} \right) \right\} + p_2 v_6.$$

The amount of sensible heat that has become latent is that required to evaporate $D_2 v_6$ kilogs. of vapor.

As the evaporation takes place not at any particular temperature, but throughout the entire range from $t_1$ to $t_2$, we have taken as the latent heat of evaporation the average of the latent heats at the temperatures $t_1$ and $t_2$, which per kilogram is $\frac{\lambda_1 + \lambda_2}{2}$. Hence the amount of heat which has become latent is, in kilogrammeters,

$$D_2 v_6 \times \frac{\lambda_1 + \lambda_2}{2} + 424.$$

As all the sensible heat that has disappeared has been either changed into work or into latent heat, we may write the equation

$$D_1 v_1 K \times (\tau_1 - \tau_2) \times 424 = JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left( 1 + \log_e \frac{\tau_1}{\tau_2} \right) \right\} + p_2 v_6 + D_2 v_6 \frac{\lambda_1 + \lambda_2}{2} \times 424$$

It may be seen by inspection that all the quantities in this equation are known except $v_6$. We can therefore find $v_6$, and hence, D. Solving for $v_6$, we have

* The volume occupied by the fluid in the liquid state is so small in comparision with that assumed by the vapor that it may be considered as equal to 0.

$$v_6 = \frac{D_1 v_1 K (t_1 - t_2) \times 424 - JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left( 1 + \log_e \frac{\tau_1}{\tau_2} \right) \right\}}{p_2 + D_2 \frac{\lambda_1 + \lambda_2}{2} \times 424}$$

15. The quantities necessary for the solution of this equation, those used in substituting in previous equations and the results of substitution, are given in the following tables in both metric and British units.

The diagrams showing the behavior of each of the vapors when worked in Carnot's cycle, are found in Fig. 2 of Plate 1.

TABLE I.

DATA AND RESULTS FOR CASE I.

METRIC UNITS.

| Vapors. | $t_1$. | $t_2$. | $t_4$. | $t_5$. | $\tau_1$. | $\tau_2$. | $\tau_4$. | $\tau_5$. |
|---|---|---|---|---|---|---|---|---|
| | Cent. | Cent. | Cent. | Cent. | Cent. | Cent. | Cent. | Cent. |
| Water | 172 | 90 | 145 | 120 | 445 | 363 | 418 | 393 |
| Alcohol | 172 | 90 | 145 | 120 | 445 | 363 | 418 | 393 |
| Ether | 172 | 90 | 145 | 120 | 445 | 363 | 418 | 393 |
| Carbon di-sulphide | 172 | 90 | 145 | 120 | 445 | 363 | 418 | 393 |
| Chloroform | 172 | 90 | 145 | 120 | 445 | 363 | 418 | 393 |

| Vapors. | $p_1$. | $p_2$. | $p_4$. | $p_5$. | $\lambda_1$. | $\lambda_2$. | $\lambda_4$. | $\lambda_5$. |
|---|---|---|---|---|---|---|---|---|
| | Kgms on sq. mets. | Kgms on sq. mets. | Kgms on sq. mets. | Kgms on sq. mets. | Calories. | Calories. | Calories. | Calories. |
| Water | 84,518 | 7,043 | 42,500 | 20,278 | 483 | 542 | 504.7 | 522.6 |
| Alcohol | 164,600 | 16,170 | 87,829 | 43,955 | 159 | 206 | 173.1 | 186.8 |
| Ether | 318,970 | 53,013 | 176,215 | 104,978 | 55.2 | 80 | 64.6 | 72.3 |
| Carbon di-sulphide | 179,230 | 35,618 | 112,023 | 70,026 | 60.1 | 78 | 66.7 | 72.2 |
| Chloroform | 145,720 | 25,337 | 90,005 | 53,394 | 49.2 | 58.1 | 52.2 | 54.9 |

| Vapors. | $D_1$. | $D_2$. | $D_4$. | $D_5$. | $r$. | $r_4$. | $r_5$. | $k$. |
|---|---|---|---|---|---|---|---|---|
| | Kgms pr cu. met. | Kgms pr cu. met. | Kgms pr cu. met. | Kgms pr cu. met. | | | | |
| Water | 5.07 | .467 | 2.63 | 1.29 | 9.37 | 1.83 | 3.57 | 1 |
| Alcohol | 25.18 | 2.74 | 13.87 | 7.16 | 8.97 | 1.83 | 3.54 | .966 |
| Ether | 78.66 | 14.47 | 44.82 | 27.50 | 6.11 | 1.85 | 3.11 | .607 |
| Carbon di-sulphide | 45.37 | 9.98 | 29.26 | 18.90 | 3.96 | 1.47 | 2.18 | .257 |
| Chloroform | 57.84 | 11.13 | 36.85 | 22.50 | 5.22 | 1.58 | 2.60 | .246 |

| Vapors. | $v_1$. | $v_2$. | $v_4$. | $v_5$. | Work of Expansion | Work of Compression | Effective Work. | Heat Used. | Efficiency |
|---|---|---|---|---|---|---|---|---|---|
| | cubic mets. | cu. m's. | cu. m's. | cu. m's. | Kilogram-meters. | Kilogram-meters. | Kilogram-meters. | Kilogram-meters. | Per cent. |
| Water | 1 | 9.37 | 1.83 | 3.57 | 274,767 | 83,408 | 191,359 | 1,038,300 | 18.43 |
| Alcohol | .6116 | 5.48 | 1.12 | 2.17 | 331,222 | 139,863 | 191,359 | 1,038,300 | 18.43 |
| Ether | .5640 | 3.45 | 1.04 | 1.75 | 466,740 | 275,381 | 191,359 | 1,038,300 | 18.43 |
| Carbon di-sulphide | .8980 | 3.56 | 1.32 | 1.95 | 354,120 | 162,761 | 191,359 | 1,038,300 | 18.43 |
| Chloroform | .8615 | 4.50 | 1.36 | 2.24 | 347,474 | 156,115 | 191,359 | 1,038,300 | 18.43 |

## TABLE II.

### DATA AND RESULTS FOR CASE I.

BRITISH UNITS.

| Vapors. | $t_1$ | $t_2$ | $t_4$ | $t_5$ | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ | $p_1$ |
|---|---|---|---|---|---|---|---|---|---|
| | Fah. | Fah. | Fah. | Fah. | Fah. | Fah. | Fah. | Fah. | Lbs. on sq. foot. |
| Water | 342 | 194 | 193 | 248 | 803 2 | 655 2 | 754.2 | 709.2 | 17,310 |
| Alcohol | 342 | 194 | 193 | 248 | 803.2 | 655.2 | 754.2 | 709.2 | 33,712 |
| Ether | 342 | 194 | 193 | 248 | 803 2 | 655.2 | 754 2 | 709.2 | 65,328 |
| Carbon di-sulphide | 342 | 194 | 193 | 248 | 803.2 | 655.2 | 754 3 | 709.2 | 36,708 |
| Chloroform | 342 | 194 | 193 | 248 | 803.2 | 655.2 | 754.2 | 709.2 | 29,845 |

| Vapors. | $p_2$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_2$ | $\lambda_4$ | $\lambda_5$ | $D_1$ | $D_2$ |
|---|---|---|---|---|---|---|---|---|---|
| | Lbs. on sq. foot. | Lbs. on sq. foot. | Lbs. on sq. foot. | Thermal units. | Ther. units. | Ther. units. | Ther. units. | Lbs. per cu. foot. | Lbs. per cu. foot. |
| Water | 1,442 | 8,705 | 4,153 | 869.4 | 975.6 | 908.5 | 940.7 | .317 | .029 |
| Alcohol | 3,312 | 17,989 | 9,003 | 286.2 | 370.8 | 311.6 | 336.2 | 1.572 | .171 |
| Ether | 10,858 | 36,090 | 21,501 | 99.4 | 144 | 116.3 | 130.1 | 4.911 | .903 |
| Carbon di-sulphide | 7,295 | 22,943 | 14,342 | 108.2 | 140.4 | 120.1 | 130.0 | 2.832 | .623 |
| Chloroform | 5,189 | 18,433 | 10,936 | 92.6 | 104.6 | 94.0 | 98.8 | 3.611 | .695 |

| Vapors. | $D_4$ | $D_5$ | $r$ | $r_4$ | $r_5$ | $v_1$ | $v_2$ | $v_4$ | $v_5$ |
|---|---|---|---|---|---|---|---|---|---|
| | Lbs. per cu. foot. | Lbs. per cu. foot. | | | | Cu. feet. | Cu. feet. | Cu. feet. | Cu. feet. |
| Water | .164 | .081 | 9.37 | 1.83 | 3.51 | 1 | 9.37 | 1.83 | 3.51 |
| Alcohol | .866 | .447 | 8.97 | 1.83 | 3.54 | .6116 | 5.48 | 1.12 | 2.17 |
| Ether | 2.798 | 1.717 | 6.11 | 1.85 | 3.11 | .5640 | 3.45 | 1.04 | 1.75 |
| Carbon di-sulphide | 1.827 | 1.180 | 3.96 | 1.47 | 2.18 | .8980 | 3.56 | 1.32 | 1.95 |
| Chloroform | 2.301 | 1.405 | 5.22 | 1.58 | 2.60 | .8615 | 4.56 | 1.36 | 2.24 |

| Vapors. | K | Work of Expansion. | Work of Compression | Effective Work. | Heat used. | Efficiency. |
|---|---|---|---|---|---|---|
| | | Kilog'meters | Kilog'meters | Kilog'meters | Kilog'meters | |
| Water | 1 | 56,275 | 17,083 | 39,192 | 212,654 | 18.43 % |
| Alcohol | .966 | 67,857 | 28,645 | 39,192 | 212,654 | 18.43 % |
| Ether | .607 | 95,593 | 56,401 | 39,192 | 212,654 | 18.43 % |
| Carbon di-sulphide | .257 | 72,527 | 33,335 | 39,192 | 212,654 | 18.43 % |
| Chloroform | .246 | 71,166 | 31,974 | 39,192 | 212,654 | 18.43 % |

### CASE II.

16. The object of this case is to determine which of the fluids—water, alcohol, ether, bi-sulphide of carbon and chloroform—would be most suitable as the working fluid of an engine, if worked as saturated vapor in a non-conducting cylinder between the limits of pressure usually employed in the steam engine.

Rankine's formulas, eqs. (1) and (2), for ratio of expansion and work done are applicable to this case, and we must now find the quantities necessary for substitution. These quantities, together with a brief statement of how they are obtained, will be given, and, at the end of this division, the necessary data and results will be tabulated in both metric and British units.

17. The pressures assumed are $p_1$= 6214.6 mm. of mercury, or 84518 kilograms per square meter, $p_2$=517.9 mm. of mercury, or 7403 kilograms per square meter. The temperatures corresponding to this pressure are found in tables given by Regnault in his "*Expériences*," and are—

| | $t_1$. | $t_2$. | $\tau_1$. | $\tau_2$. |
|---|---|---|---|---|
| Water | 172 | 90 | 445 | 363 |
| Alcohol | 144 | 69 | 417 | 342 |
| Ether | 110 | 24½ | 383 | 297½ |
| Bi-sulph. of carb. | 130 | 35 | 403 | 308 |
| Chloroform | 141 | 49 | 414 | 322 |

To find $D_1$, the weight in kilograms per cubic meter of saturated vapor, we have formula (9)—

$$D_1 = \frac{p_1 \delta}{36.2\sqrt{a+t}}$$

The values of $\delta$ are given in §9. Substituting in the formula, we get,

| | $D_1$. | $D_2$. |
|---|---|---|
| Water | 5.07 | .467 |
| Alcohol | 13.36 | 1.23 |
| Ether | 22.42 | 2.12 |
| Bi-sulph. of carb. | 22.41 | 2.14 |
| Chloroform | 34.78 | 3.29 |

The latent heats of evaporation, $L_1$ and $L_2$, per cubic meter of vapor at temperature $t_1$ and $t_2$, expressed in kilogrammeters are found as in §10, and are—

| | $L_1$. | $L_2$. |
|---|---|---|
| Water | 1,038,300 | 107,300 |
| Alcohol | 985,600 | 115,256 |
| Ether | 713,000 | 82,337 |
| Bi-sulph. of carb. | 665,100 | 78,305 |
| Chloroform | 775,600 | 86,766 |

The mean specific heats are found as in §11, but will differ from those previously found, as the ranges of temperature are not the same. They are—

| | K. |
|---|---|
| Water | 1 |
| Alcohol | .871 |
| Ether | .569 |
| Bi-sulp. of carb. | .249 |
| Chloroform | .242 |

It is to be remembered that $t_1$ and $t_2$ have different values for each of the vapors.

18. Having now all the data necessary for substitution in formula (1),

$$r = \frac{\tau_2}{L_2}\left( JKD_1 \log_e \frac{\tau_1}{\tau_2} + \frac{L_1}{\tau_1} \right)$$

we may find the ratios of expansion, which are—

| | $r = rv_1 = v_2$. |
|---|---|
| Water | 9.37 |
| Alcohol | 9.92 |
| Ether | 12.06 |
| Bi-sulph. of carb. | 9.00 |
| Chloroform | 10.29 |

To find the work done we substitute in formula (2),

$$W = \text{work} = JKD_1 \left\{ \tau_1 - \tau_2 \left( 1 + \log_e \frac{\tau_1}{\tau_2} \right) \right\} + \\ + \frac{\tau_1 - \tau_2}{\tau_1} L_1 + r(p_3 - p_2)$$

To this substitution, we have all the quantities except $p_2$, the back pressure, which is determined by the temperature of the condenser. As the temperature of the condenser cannot easily be kept lower than 104° Fahr., or 40° Centigrade, we have assumed that to be its temperature, and $p_2$ must, in each case, be the tension of the vapor corresponding to this temperature.

From Regnault's tables we have,

| | $p_2$ (m.m. of Mercury). | $p_2$ (kilogs. per sq. meter). |
|---|---|---|
| Water | 55 | 748 |
| Alcohol | 134 | 1,825 |
| Ether | 907 | 12,335 |
| Bi-sulph. of carb | 618 | 8,405 |
| Chloroform | 366 | 4,973 |

Making the proper substitutions we obtain for work done:

| | | |
|---|---|---|
| Water | 267,705 | kilogrammeters. |
| Alcohol | 264,617 | " |
| Ether | 151,643 | " |
| Bi-sulph. of carb. | 173,553 | " |
| Chloroform | 232,456 | " |

19. To determine the *efficiency of fluid* of the several vapors, we must first find the heat expended per cubic meter of vapor at temperature $t_1$. As the feed for the boiler is taken from the surface-condenser, its temperature is $t_2$. The heat used is then the amount necessary to raise $D_1$ kilograms of liquid from temperature $t_2$ to $t_1$, and to evaporate them at that temperature.

20. This is most easily found by calculating the total heat of evaporation from 0° C. to $t_1$, and subtracting from this quantity the heat required to raise the liquid from 0° to $t_2$.

The total heat of evaporation per kilogram from 0° to $t$ is given by the formula

$$Q = A + Bt + Ct^2$$

(p. 640, Wüllner's "*L. v. d. W.*").

The constants for ether, bi-sulphide of carbon and chloroform, are—

| | A. | B. | C. |
|---|---|---|---|
| Ether | 94 | .4500 | −.0005555 |
| Bi-sulph. of carb. | 90 | .14601 | −.0004123 |
| Chloroform | 67 | .1375 | 0 |

The value for alcohol was determined from the table on page 641, "*L. v. d. W.*" by interpolation, and that for water was determined by the same method from the table on p. 635 of the same work.

The total heats of evaporation at temperature $t_1$ per kilogram, expressed in calories, are—

| | $t_1$. | $Q_1$. |
|---|---|---|
| Water | 172 | 659.0 |
| Alcohol | 144 | 282.5 |
| Ether | 110 | 136.8 |
| Bi-sulph. of carb. | 130 | 102.0 |
| Chloroform | 141 | 86.4 |

The same quantities for $D_1$ kilogs. of vapor, expressed in kilogrammeters, are given by

$$H_1 = 424 \times D_1 \times Q_1,$$

and are

| | $H_1$. |
|---|---|
| Water | 1,416,639 |
| Alcohol | 1,600,261 |
| Ether | 1,300,431.7 |
| Bi-sulph. of carb. | 969,188 |
| Chloroform | 1,274,117 |

The amount of heat, $h_2$, expressed in mechanical units, necessary to raise the temperature of the liquid from 0 to $t_2$ is found by multiplying the mean specific heat for that range of temperature by $(t_2 - 0)$, $D_1$ and 424.

On page 483, "*L. v. d. W.*" the following formula is given for the mean specific heat between 0 and $t$:

$$C_t = A + Bt + Ct^2,$$

in which A, B and C have the values given in §11.

Hence,

$$h_2 = C_t \times D_1 \times 40 \times 424.$$

The values of $h_2$ are

| | $h_2$. |
|---|---|
| Water | 86,000 |
| Alcohol | 135,054 |
| Ether | 205,710 |
| Bi-sulph of carb. | 90,459 |
| Chloroform | 138,032 |

The efficiency of fluid is the work divided by the mechanical equivalent of the heat used, or

$$E = \frac{W}{H_1 - h_2} = \frac{W}{H}$$

| | $H = H_1 - h_2$. | E. |
|---|---|---|
| Water | 1,330,639 | 20.12 % |
| Alcohol | 1,465,207 | 18.06 % |
| Ether | 1,094,722 | 13.85 % |
| Bi-sulph. of carb. | 878,729 | 19.75 % |
| Chloroform | 1,136,085 | 20.46 % |

These efficiencies are different, as they should be, the fluids being worked through different ranges of temperature.

To show the relation between the power developed per stroke, and the size of cylinder for each of these vapors, the power developed in a cylinder one cubic meter in volume is calculated. As, in the problem just discussed, the initial volume of vapor was one cubic meter, the volume of cylinder, $v_2$, required for its working is $r$ cu. meters. It thus follows that, in a cylinder of one cubic meter capacity, the work done would be $\frac{W}{r}$. The values of this ratio are—

| | $\frac{W}{r}$ |
|---|---|
| Water | 28,570 |
| Alcohol | 26,675 |
| Ether | 12,574 |
| Bi-sulph. of carb | 19,284 |
| Chloroform | 22,590 |

To render the comparison of these numbers easier, the ratio of each to that of water is taken. These ratios give the relative powers developed in cylinders of the same size; their reciprocals give the relative volumes of cylinder required to produce the same power.

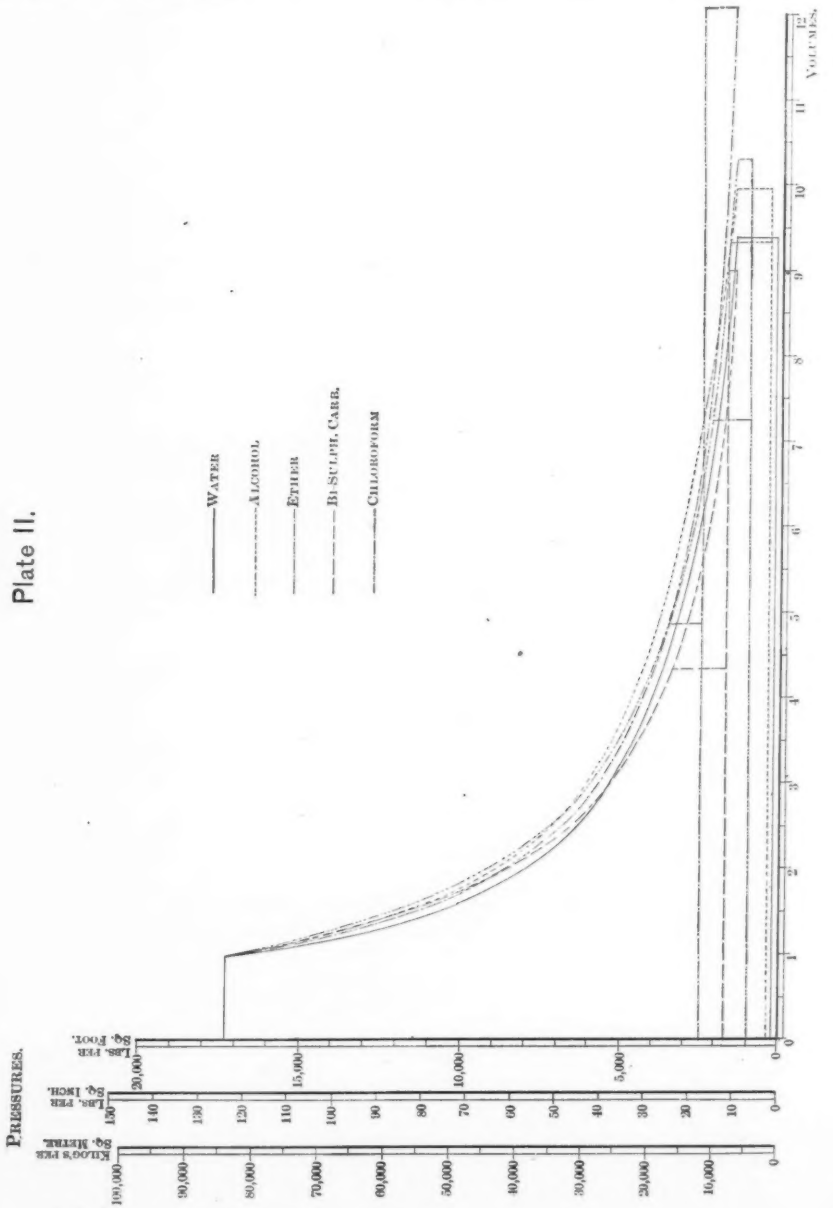
| | Ratio. | Reciprocal. |
|---|---|---|
| Water | 1. | 1. |
| Alcohol | .934 | 1.071 |
| Ether | .440 | 2.275 |
| Bi-sulph. of carb. | .676 | 1.480 |
| Chloroform | .791 | 1.264 |

From the above, it is seen that steam requires the smallest cylinder to produce a given power, if worked between the limits of pressure we have taken. It is also more efficient than any of the vapors, except chloroform. The losses due

to the larger cylinder necessary to work chloroform would probably bring down its efficiency in practice, at least to that of steam if not lower. So far, then, it would seem that steam is the best fluid to use in heat engines.

23. As a matter of interest, we have constructed theoretical indicator cards for the vapors studied, showing how expansion would take place in a heat-engine cylinder. These cards are shown in Plate II. Two temperatures, $t_1$ and $t_2$,

Plate II.



were taken between $t_1$ and $t_2$, and the corresponding pressures found from tables in Regnault's "*Expériences*," or by the formula (5) of §8. The volumes were calculated by Rankine's formula for ratio of expansion, as modified in §13; the initial volume being unity, the formula becomes—

$$r_4 = \frac{\tau_4}{\lambda_4 D_4}\left(KD_1 \log_e \frac{\tau_1}{\tau_4} + \frac{\lambda_1 D_1}{\tau_1}\right)$$

$\lambda_4$ and $\lambda_5$ were calculated as in §10, and $D_4$ and $D_5$ as in §9. K is nearly the same as in §7.

In Tables III. and IV. are given, in both metric and British units, all the data necessary for this case, together with the results of substitution.

The final volume, $v_2 = rv_1$; but as $v_1 = 1$, $v_2 = r$; hence, $v_2$ and not $r$, is found in the tables.

24. Before giving the tables, we shall define the various quantities that appear in them.

METRIC UNITS.

$\tau_1$, absolute initial temperature on the C. scale.

$\tau_2$, absolute final temperature on same scale.

$\tau_4$ and $\tau_5$, absolute temperatures of intermediate points.

$t_1$, temperature on C. scale, corresponding to absolute temperature $\tau_1$

$t_2$, temperature of condenser.

$p$, tension of vapor in kilogs. per sq. meter at temperature $t$.

$\lambda$, latent heat of evaporation in calories of 1 kilog. of vopor at temperature $t$.

L, latent heat of evaporation in k g.m. at temperature $t$ of 1 cu. m. of vapor.

$v$, volume corresponding to ratio of expansion $r$.

$w$, work (in k.g.m.) done per cu. m. of vapor at temperature $t_1$.

H, total heat (in k. g.m.) used per cu. m. of vapor at temperature $t$.

F, kilograms used per H. P. per hour.

M, relative size of cylinder to produce the same power.

BRITISH UNITS.

$\tau_1$, absolute initial temperature on the Fahr. scale.

$\tau_2$, absolute final temperature on same scale.

$\tau_4$ and $\tau_5$, absolute temperatures of intermediate points.

$t_1$, temperature on F. scale corresponding to absolute temperature $\tau_1$.

$t_2$, temperature of condenser.

$p$, tension of vapor in lbs. per square ft. at temperature $t$.

$\lambda$, latent heat of evaporation in British thermal units of 1 lb. of vapor at temperature $t$.

L, latent heat of evaporation of 1 cu. ft. of vapor in ft. lbs. at temperature $t$.

$v$, volume corresponding to ratio of expansion $r$.

$w$, work (in ft. lbs.) done per cu. ft. of vapor at temperature $t_1$.

H, total heat (in ft. lbs.) used per cu. ft. of vapor at temperature $t$.

F, lbs. used per H. P. per hour.

M, relative size of cylinder to produce the same power.

## TABLE III.

DATA AND RESULTS IN CASE II.

METRIC UNITS.

| Vapors. | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ | $t_1$ | $t_2$ | $D_1$ | $D_4$ | $D_5$ |
|---|---|---|---|---|---|---|---|---|---|
| Water | 445 | 363 | 418 | 393 | 172 | 40 | 5.07 | 2.63 | 1.29 |
| Alcohol | 417 | 342 | 393 | 353 | 144 | 40 | 13.36 | 3.86 | 1.90 |
| Ether | 383 | 297.5 | 393 | 353 | 110 | 40 | 22.42 | 18.14 | 11.40 |
| Bi-sulph. of carb. | 403 | 308 | 393 | 353 | 130 | 40 | 22.41 | 12.50 | 7.80 |
| Chloroform | 414 | 322 | 393 | 353 | 141 | 40 | 34.78 | 14.31 | 8.50 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_4$ | $\lambda_5$ | K |
|---|---|---|---|---|---|---|---|---|---|
| Water | 84,518 | 7,043 | 748 | 42,500 | 20,278 | 483 | 504.7 | 522.6 | 1 |
| Alcohol | 84,518 | 7,043 | 1,822 | 23,093 | 11,057 | 174 | 199. | 213. | .871 |
| Ether | 84,518 | 7,043 | 12,335 | 67,361 | 41,113 | 75 | 77.6 | 82.2 | .569 |
| Bi-sulph. of carb. | 84,518 | 7,043 | 8,405 | 45,220 | 27,649 | 70 | 76.1 | 79.7 | .249 |
| Chloroform | 84,518 | 7,043 | 4,978 | 33,021 | 25,894 | 52.6 | 57. | 59.1 | .242 |

| Vapors. | $L_1$ | $L_2$ | $v_2$ | $v_4$ | $v_5$ | W | H | E | M | F |
|---|---|---|---|---|---|---|---|---|---|---|
| Water..... | 1,038,300 | 107,300 | 9.37 | 1.83 | 3.57 | 267,705 | 1,330,639 | 20.12 % | 1 | 5.19 |
| Alcohol..... | 985,600 | 115,256 | 9.92 | 3.97 | 8.12 | 264,617 | 1,465,207 | 18.06 % | 1.071 | 13.83 |
| Ether..... | 713,000 | 82,337 | 12.06 | 1.25 | 2.05 | 151,643 | 1,094,722 | 13.85 % | 2.275 | 40.49 |
| Bi-sulph. of carb... | 665,100 | 78,305 | 9.00 | 1 87 | 3.06 | 173,553 | 878,729 | 19.75 % | 1.480 | 35.46 |
| Chloroform..... | 775,600 | 86,766 | 10.29 | 2.68 | 4.66 | 232,456 | 1,136,085 | 20.46 % | 1.264 | 40.97 |

TABLE IV.

DATA AND RESULTS IN CASE II.

BRITISH UNITS.

| Vapors. | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ | $t_1$ | $t_5$ | $D_1$ | $D_4$ | $D_5$ |
|---|---|---|---|---|---|---|---|---|---|
| Water..... | 803 | 655 | 754 | 709 | 342 | 104 | .317 | .164 | .081 |
| Alcohol..... | 752 | 617 | 673 | 637 | 291 | 104 | .834 | .241 | .119 |
| Ether..... | 691 | 537 | 673 | 637 | 230 | 104 | 1.400 | 1.132 | .712 |
| Bi-sulph. of carb... | 727 | 556 | 673 | 637 | 266 | 104 | 1.399 | .780 | .487 |
| Chloroform..... | 747 | 581 | 673 | 637 | 286 | 104 | 2.171 | .893 | .531 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_4$ | $\lambda_5$ | K |
|---|---|---|---|---|---|---|---|---|---|
| Water..... | 17,310 | 1,442 | 153 | 8,703 | 4,512 | 869.4 | 908.5 | 940.7 | 1 |
| Alcohol..... | 17,310 | 1,442 | 373 | 4,730 | 2,264 | 313.2 | 358.2 | 383.4 | .871 |
| Ether..... | 17,310 | 1,442 | 2,526 | 13,796 | 8,420 | 135.0 | 139.7 | 148.0 | .569 |
| Bi-sulph. of carb... | 17,310 | 1,442 | 1,721 | 9,261 | 5,663 | 126.0 | 137.0 | 143.5 | .249 |
| Chloroform..... | 17,310 | 1,442 | 1,020 | 6,763 | 3,911 | 94.7 | 102.6 | 106.4 | .242 |

| Vapors. | $L_1$ | $L_2$ | $v_2$ | $v_4$ | $v_5$ | W | H | E | M | F |
|---|---|---|---|---|---|---|---|---|---|---|
| Water..... | 212,654 | 21,976 | 9.37 | 1.83 | 3.57 | 54,829 | 272,528 | 20.12 % | 1 | 11.44 |
| Alcohol..... | 201,861 | 23,606 | 9.92 | 3.97 | 8.12 | 54,196 | 300,088 | 18.06 % | 1.071 | 30.48 |
| Ether..... | 146,030 | 16,863 | 12.06 | 1.25 | 2.05 | 31,058 | 324,206 | 13.85 % | 2.275 | 89.24 |
| Bi-sulph. of carb... | 136,219 | 16,038 | 9.00 | 1.87 | 3.06 | 35,545 | 179,973 | 19.75 % | 1.480 | 78.15 |
| Chloroform..... | 158,851 | 17,771 | 10.29 | 2.68 | 4.66 | 47,609 | 232,685 | 20.46 % | 1.264 | 90.30 |

25. From the indicator cards shown in Plate II., it may be seen that the ratios of expansion adopted in the last case are not most economical, especially in the cases of ether and bi-sulphate of carbon, in which cases the final pressure is lower than the back pressure, causing a loop in the expansion and exhaust lines. It has been found in steam-engine practice that it is not economical to expand down to the back pressure, the best results having been obtained when there is a difference between final and back pressure of from 7 to 10 lbs. on the square inch. It is probable that the best practical results, in the cases of the other vapors, would be obtained by producing a similar difference between final and back pressure. This assumption suggests a modification of Case II., which is given as Case III.

CASE III.

26. In this case we have taken the same initial pressures as in the last, but have determined the final pressure by adding a nearly constant quantity to the back pressure, which latter pressure is determined by the temperature of the condenser, 40° C.

The formulæ (1) and (2) used to find the ratio of expansion and work done are the same as used in the last case. The symbols having subscripts (1) and (3) are the same as in the preceding case, those quantities represented by symbols having (2) for a subscript must now be found.

The pressures $p_2$ and $p_3$ are given below in kilograms on the square meter.

| | $p_2$. | $p_3$. |
|---|---|---|
| Water | 7,043 | 748 |
| Alcohol | 7,358 | 1,828 |
| Ether | 17,190 | 12,335 |
| Bi-sulph. of carb. | 15,844 | 8,405 |
| Chloroform | 10,214 | 4,978 |

The temperatures $t_2$ corresponding to the pressures $p_2$, were found from the tables in Regnault's "*Expériences.*" $D_2$ is determined as in § 9; $\lambda_2$ as in § 10. With these data, and those of Case II., we may now find the values of the new ratio of expansion work done, and efficiency.

27. The data for this problem, together with the results obtained, are to be found in Tables V. and VI., in which the letters at the heads of the columns have the same signification as explained in § 24.

TABLE V.

DATA AND RESULTS IN CASE III.

METRIC SYSTEM.

| Vapors. | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ | $t_1$ | $t_2$ | $D_1$ | $D_2$ | $D_4$ | $D_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Water | 445 | 363 | 418 | 393 | 172 | 40 | 5.07 | .467 | 2.63 | 1.29 |
| Alcohol | 417 | 343 | 393 | 353 | 144 | 40 | 13.36 | 1.28 | 3.86 | 1.90 |
| Ether | 383 | 323 | 393 | 353 | 110 | 40 | 22.42 | 4.97 | 18.14 | 11.40 |
| Carbon di-sulphide. | 403 | 333 | 393 | 353 | 130 | 40 | 22.41 | 4.63 | 12.50 | 7.80 |
| Chloroform | 414 | 333 | 393 | 353 | 141 | 40 | 34.78 | 4.69 | 14.31 | 8.50 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_4$ | $\lambda_5$ | K | $L_1$ | $L_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water | 84,518 | 7,043 | 748 | 42,500 | 20,278 | 483 | 504.7 | 522.6 | 1 | 1,038,300 | 107,320 |
| Alcohol. | 84,518 | 7,358 | 1,822 | 23,093 | 11,057 | 174 | 199 | 213 | .871 | 985,600 | 119,941 |
| Ether | 84,518 | 17,190 | 12,335 | 67,361 | 41,113 | 75 | 77.6 | 82.2 | .569 | 713,000 | 185,226 |
| Carb. di-sulph. | 84,518 | 15,844 | 8,405 | 45,220 | 27,649 | 70 | 76.1 | 79.7 | .249 | 665,100 | 162,743 |
| Chloroform | 84,518 | 10,214 | 4,978 | 33,021 | 25,894 | 52.6 | 57 | 59.1 | .242 | 775,600 | 121,501 |

| Vapors. | $v_2$ | $v_4$ | $v_5$ | W | H | E | M |
|---|---|---|---|---|---|---|---|
| Water | 9.37 | 1.83 | 3.57 | 267,705 | 1,330,639 | 20.12 % | 1 |
| Alcohol | 9.51 | 3.97 | 8.12 | 262,614 | 1,465,207 | 17.92 % | 1.035 |
| Ether | 4.85 | 1.25 | 2.05 | 162,869 | 1,094,722 | 14.88 % | .845 |
| Carbon di-sulphide. | 4.31 | 1.87 | 3.06 | 162,875 | 878,729 | 18.53 % | .756 |
| Chloroform | 7.24 | 2.68 | 4.66 | 219,200 | 1,136,084 | 19.29 % | .944 |

TABLE VI.

DATA AND RESULTS IN CASE III.

BRITISH UNITS.

| Vapors. | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ | $t_1$ | $t_2$ | $D_1$ | $D_2$ | $D_4$ | $D_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Water | 803 | 655 | 754 | 709 | 342 | 104 | .317 | .029 | .164 | .081 |
| Alcohol | 752 | 619 | 673 | 637 | 291 | 104 | .834 | .080 | .241 | .119 |
| Ether | 691 | 583 | 673 | 637 | 230 | 104 | 1.400 | .310 | 1.132 | .712 |
| Carbon di-sulphide. | 727 | 601 | 673 | 637 | 266 | 104 | 1.399 | .289 | .780 | .487 |
| Chloroform | 747 | 601 | 673 | 637 | 286 | 104 | 2.171 | .293 | .893 | .531 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_4$ | $\lambda_5$ | K | $L_1$ | $L_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water | 17,310 | 1,442 | 153 | 8,703 | 4,512 | 869.4 | 908.5 | 940.7 | 1 | 212,650 | 21,980 |
| Alcohol | 17,310 | 1,507 | 373 | 4,730 | 2,264 | 313.2 | 358.2 | 383.4 | .871 | 201,861 | 24,565 |
| Ether | 17,310 | 3,524 | 2,526 | 13,796 | 8,420 | 135.0 | 139.7 | 148.0 | .569 | 146,030 | 37,936 |
| Carbon di-sulphide. | 17,310 | 3,245 | 1,721 | 9,261 | 5,663 | 126.0 | 137.0 | 143.5 | .249 | 136,219 | 33,331 |
| Chloroform | 17,310 | 2,092 | 1,020 | 6,763 | 3,911 | 94.7 | 102.6 | 106.4 | .242 | 158,851 | 24,885 |

| Vapors. | $v_2$ | $v_4$ | $v_5$ | W | H | E | M |
|---|---|---|---|---|---|---|---|
| Water | 9.37 | 1.83 | 3.51 | 54,829 | 1,330,639 | 20.12% | 1 |
| Alcohol | 9.51 | 3.97 | 8.12 | 53,786 | 1,465,207 | 17.92% | 1.035 |
| Ether | 4.85 | 1.25 | 2.05 | 33,357 | 1,094,722 | 14.88% | .845 |
| Carbon di-sulphide | 4.31 | 1.87 | 3.06 | 33,358 | 878,729 | 18.53% | .756 |
| Chloroform | 7.24 | 2.68 | 4.66 | 44,894 | 1,136,084 | 19.29% | .944 |

The indicator cards for this case are given in Plate II. They differ from those of Case II. only in the value of the ratio of expansion.

28. On comparison with Tables V. and VI. with Tables III. and IV., it will be seen that the efficiences in the latter case are greater than those in the former. It must be remembered, however, that in practice the losses by friction and condensation due to greater ratios of expansion in Problem II. will probably more than compensate for this small increase of useful work. Tables V. and VI. show, further, that steam has an advantage over all the other vapors in efficiency, and over alcohol in size of cylinder, while bi-sulphide of carbon excels all the others in the latter respect.

### Case IV.

29. In Cases II. and III. we have considered the behavior of the several vapors in question when used as working fluids between the limits of pressure common in the modern steam engine. We shall now proceed to discuss, in Cases IV. and V., their behavior when worked between the limits of *temperature* used in the steam engine. The pressures assumed in the two preceding problems were $p_1 = 84{,}518$ kilograms per square meter, and $p_2 = 7{,}043$ kilograms per square meter. The temperatures of saturated water vapor under these pressures are $t_1 = 172°$ C., and $t_2 = 90°$ C. The temperature of the condenser is, as before, taken as 40° C., which is as low as it could be conveniently kept in practice.

The tensions of the saturated vapors of alcohol, ether, bisulphide of carbon, and chloroform, at these temperatures, have already been found in Case 1, § 8. In the same problem were also determined the values of $D_1$ and $D_2$, § 9; of $\lambda_1$ and $\lambda_2$, § 10; of K, § 11, and of $r$, § 12; while § 13 furnishes the value of $D_4$, $D_5$, $\lambda_4$, $\lambda_5$, $p_4$, $p_5$, $r_4$, and $r_5$.

Tables VII. and VIII. contain the data and results for this case; the corresponding indicator cards are found in Plate III. As the initial volume $v_1$, in the case under consideration, is one cubic meter, the final volumes, $v_2$, $v_4$ and $v_5$, will be different from the similar quantities in Case I., and will be numerically equal to the ratios of expansion $r_2$, $r_4$ and $r_5$. The letters at the head of the columns of the tables have the same signification as before explained.

### Table VII.

Data and Results for Case IV.

METRIC UNITS.

| Vapors. | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ |
|---|---|---|---|---|---|---|---|---|---|
| Water | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 | 393 |
| Alcohol | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 | 393 |
| Ether | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 | 393 |
| Carbon di-sulphide | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 | 393 |
| Chloroform | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 | 393 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_2$ | $\lambda_4$ | $\lambda_5$ | K |
|---|---|---|---|---|---|---|---|---|---|---|
| Water | 84,518 | 7,043 | 748 | 42,500 | 20,278 | 483 | 542 | 504.7 | 523.6 | 1 |
| Alcohol | 164,600 | 16,170 | 1,822 | 87,829 | 43.955 | 159 | 206 | 173.1 | 186.8 | .966 |
| Ether | 318,970 | 53,013 | 12,335 | 176,215 | 104,978 | 55.2 | 80 | 64.6 | 72.3 | .607 |
| Carbon di-sulphide. | 179,230 | 35,618 | 8,405 | 112,023 | 70,026 | 60.1 | 78 | 66.7 | 72.2 | .257 |
| Chloroform | 145,720 | 25,337 | 4,978 | 90,005 | 53,394 | 49.2 | 58.1 | 52.2 | 54 9 | .246 |

| Vapors. | $D_1$ | $D_2$ | $D_4$ | $D_5$ | $v_2$ | $v_4$ | $v_5$ |
|---|---|---|---|---|---|---|---|
| Water | 5.07 | .467 | 2.63 | 1.29 | 9·37 | 1.83 | 3.57 |
| Alcohol | 25.18 | 2.74 | 13.87 | 7.16 | 8.97 | 1.83 | 3.54 |
| Ether | 78.66 | 14.47 | 44.82 | 27.50 | 6.11 | 1.85 | 3.11 |
| Carbon di-sulphide. | 45.37 | 9.98 | 29.26 | 18.90 | 3.96 | 1.47 | 2.18 |
| Chloroform | 57.84 | 11.13 | 36 85 | 22.50 | 5.22 | 1.58 | 2.60 |

| Vapors. | W. | H. | E. | F. | M. |
|---|---|---|---|---|---|
| Water | 267,705 | 1,330,639 | 20.12% | 5.19 | 1 |
| Alcohol | 525,086 | 2,894,904 | 18.14% | 13.13 | .488 |
| Ether | 751,821 | 4,447,823 | 16.90% | 28.64 | .232 |
| Carbon di-sulphide | 360,878 | 1,798,275 | 20.07% | 34.41 | .314 |
| Chloroform | 376,517 | 2,002,139 | 18.81% | 42.06 | .396 |

## TABLE VIII.

### DATA AND RESULTS FOR CASE IV.

BRITISH UNITS.

| Vapors. | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ | $\tau_1$ | $\tau_2$ | $\tau_4$ | $\tau_5$ |
|---|---|---|---|---|---|---|---|---|---|
| Water | 342 | 194 | 104 | 293 | 248 | 803.2 | 655.2 | 754.2 | 709.2 |
| Alcohol | 342 | 194 | 104 | 293 | 248 | 803.2 | 655.2 | 754.2 | 709.2 |
| Ether | 342 | 194 | 104 | 293 | 248 | 803.2 | 655.2 | 754.2 | 709.2 |
| Carbon di-sulphide | 342 | 194 | 104 | 293 | 248 | 803.2 | 655.2 | 754.2 | 709.2 |
| Chloroform | 342 | 194 | 104 | 293 | 248 | 803.2 | 655.2 | 754.2 | 709.2 |

| Vapors. | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_2$ | $\lambda_4$ | $\lambda_5$ |
|---|---|---|---|---|---|---|---|---|---|
| Water | 17,310 | 1,442 | 153 | 8,705 | 4,153 | 869.4 | 975.6 | 908.5 | 940.7 |
| Alcohol | 33,712 | 3,312 | 373 | 17,989 | 9,003 | 286.2 | 370.8 | 311.6 | 336.2 |
| Ether | 65,329 | 10,858 | 2,526 | 36,090 | 21,501 | 99.4 | 144 | 116.3 | 130.1 |
| Carbon di-sulphide | 36,708 | 7,295 | 1,721 | 22,943 | 14,343 | 108.2 | 140.4 | 120.1 | 130.0 |
| Chloroform | 29,845 | 5,189 | 1,020 | 18,433 | 10,936 | 92.6 | 104.6 | 94.0 | 98.8 |

| Vapors. | K | $D_1$ | $D_2$ | $D_4$ | $D_5$ | $v_2$ | $v_4$ | $v_5$ |
|---|---|---|---|---|---|---|---|---|
| Water | 1 | .317 | .029 | .164 | .081 | 9.37 | 1.83 | 3.51 |
| Alcohol | .966 | 1.572 | .171 | .866 | .447 | 8.97 | 1.83 | 3.54 |
| Ether | .607 | 4.911 | .903 | 2.798 | 1.717 | 6.11 | 1.85 | 3.11 |
| Carbon di-sulphide | .257 | 2.832 | .623 | 1.827 | 1.180 | 3.96 | 1.47 | 2.18 |
| Chloroform | .246 | 3.611 | .695 | 2.301 | 1.405 | 5.22 | 1.58 | 2.60 |

| Vapors. | W. | H. | E. | F. | M. |
|---|---|---|---|---|---|
| Water | 54,829 | 272,528 | 20.12% | 11.45 | 1 |
| Alcohol | 107,543 | 572,904 | 18.14% | 28.94 | .488 |
| Ether | 153,980 | 910,954 | 16.90% | 63.15 | .232 |
| Carbon di-sulphide | 73,911 | 368,310 | 20.07% | 75.87 | .314 |
| Chloroform | 77,114 | 410,058 | 18.81% | 92.72 | .396 |

### Case V.

30. This problem bears the same relation to Case IV. that Case III. bears to Case II. In the preceding case we did not assume the most favorable practical conditions for the working of either of the fluids with the exception of water; hence, for the reasons already stated in § 25, we shall assume for our back pressure, $p_2$, the same values as were taken in Case III.

Tables IX. and X. contain a summary in Metric and British units of the data and results for this case. The corresponding theoretical indicator cards are shown in Plate III.

### Table IX.

Data and Results for Case V.

METRIC UNITS.

| Vapors. | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ | $\tau_1$ | $\tau_2$ | $\tau_4$ |
|---|---|---|---|---|---|---|---|---|
| Water | 172 | 90 | 40 | 145 | 120 | 445 | 363 | 418 |
| Alcohol | 172 | 70 | 40 | 145 | 120 | 445 | 343 | 418 |
| Ether | 172 | 50 | 40 | 145 | 120 | 445 | 323 | 418 |
| Carbon di-sulphide | 172 | 60 | 40 | 145 | 120 | 445 | 333 | 418 |
| Chloroform | 172 | 60 | 40 | 145 | 120 | 445 | 333 | 418 |

| Vapors. | $\tau_6$ | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_2$ |
|---|---|---|---|---|---|---|---|---|
| Water | 393 | 84,518 | 7,043 | 748 | 42,500 | 20,278 | 483 | 542 |
| Alcohol | 393 | 164,600 | 7,358 | 1,822 | 87,829 | 43,955 | 159 | 221 |
| Ether | 393 | 318,970 | 17,190 | 12,355 | 176,215 | 104,978 | 55.2 | 87.9 |
| Carbon di-sulphide | 393 | 179,230 | 15,844 | 8,405 | 112,023 | 70,026 | 60.1 | 82.9 |
| Chloroform | 393 | 145,720 | 10,214 | 4,978 | 90,005 | 53,394 | 49.2 | 61.1 |

| Vapors. | $\lambda_4$ | $\lambda_5$ | K | $D_1$ | $D_2$ | $D_4$ | $D_5$ | $r_2$ |
|---|---|---|---|---|---|---|---|---|
| Water | 504.7 | 522.6 | 1 | 5.07 | .467 | 2.63 | 1.29 | 9.37 |
| Alcohol | 173.1 | 186.8 | .966 | 25.18 | 1.28 | 13.87 | 7.16 | 18.59 |
| Ether | 64.6 | 72.3 | .607 | 78.66 | 4.97 | 44.82 | 27.50 | 18.53 |
| Carbon di-sulphide | 66.7 | 72.2 | .257 | 45.37 | 4.63 | 29.26 | 18.90 | 8.25 |
| Chloroform | 52.2 | 54.9 | .246 | 57.84 | 14.69 | 36.85 | 22.50 | 12.23 |

| Vapors. | $v_4$ | $v_5$ | W | H | E | F | M |
|---|---|---|---|---|---|---|---|
| Water | 1.83 | 3.57 | 267,705 | 1,330,639 | 20.12 % | 5.19 | 1 |
| Alcohol | 1.83 | 3.54 | 622,978 | 2,894,904 | 21.52 % | 11.07 | .853 |
| Ether | 1.85 | 3.11 | 988,752 | 4,447,823 | 22.23 % | 21.78 | .535 |
| Carbon di-sulphide | 1.47 | 2.18 | 428,486 | 1,798,275 | 23.83 % | 28.98 | .550 |
| Chloroform | 1.58 | 2.60 | 462,834 | 2,002,139 | 23.12 % | 34.21 | .761 |

### Table X.

Data and Results for Case V.

BRITISH UNITS.

| Vapors. | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ | $\tau_1$ | $\tau_2$ | $\tau_4$ |
|---|---|---|---|---|---|---|---|---|
| Water | 342 | 194 | 104 | 293 | 248 | 803 | 655 | 754 |
| Alcohol | 342 | 158 | 104 | 293 | 248 | 803 | 655 | 754 |
| Ether | 342 | 122 | 104 | 293 | 248 | 803 | 655 | 754 |
| Carbon di-sulphide | 342 | 140 | 104 | 293 | 248 | 803 | 655 | 754 |
| Chloroform | 342 | 140 | 104 | 293 | 248 | 803 | 655 | 754 |

| Vapors. | $\tau_5$ | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $\lambda_1$ | $\lambda_2$ |
|---|---|---|---|---|---|---|---|---|
| Water | 709 | 17,310 | 1,442 | 153 | 8,705 | 4,153 | 869.4 | 975.6 |
| Alcohol | 709 | 33,712 | 1,507 | 373 | 17,989 | 9,003 | 286.2 | 397 8 |
| Ether | 709 | 65,328 | 3,524 | 2,526 | 36,090 | 21,501 | 99.4 | 158.1 |
| Carbon di-sulphide | 709 | 36,708 | 3,245 | 1,721 | 22,943 | 14,342 | 108.2 | 141.2 |
| Chloroform | 709 | 29,845 | 2,092 | 1,020 | 18,433 | 10,936 | 92.6 | 130.0 |

| Vapors. | $\lambda_4$ | $\lambda_5$ | K | $D_1$ | $D_2$ | $D_4$ | $D_5$ | $v_2$ |
|---|---|---|---|---|---|---|---|---|
| Water | 908.5 | 940.7 | 1 | .317 | .029 | .164 | .081 | 9.37 |
| Alcohol | 311.6 | 336.2 | .966 | 1.572 | .171 | .866 | .447 | 18.59 |
| Ether | 116.3 | 130.1 | .607 | 4.911 | .903 | 2.798 | 1.717 | 18.53 |
| Carbon di-sulphide | 120.1 | 130.0 | .257 | 2.832 | .623 | 1.827 | 1.180 | 8.25 |
| Chloroform | 94.0 | 98.8 | .246 | 3.611 | .695 | 2.301 | 1.405 | 12.23 |

| Vapors. | $v_4$ | $v_5$ | W | H | E | F | M |
|---|---|---|---|---|---|---|---|
| Water | 1.83 | 3.57 | 54,829 | 272,528 | 20.12 % | 11.44 | 1 |
| Alcohol | 1.83 | 3.54 | 127,592 | 592,904 | 21.52 % | 24.40 | .853 |
| Ether | 1.85 | 3.11 | 202,506 | 910,954 | 22.23 % | 48.02 | .535 |
| Carbon di-sulphide | 1.47 | 2.18 | 87,758 | 368,310 | 23.83 % | 63.88 | .550 |
| Chloroform | 1.58 | 2.60 | 94,793 | 410,058 | 23.12 % | 75.42 | .761 |

### Conclusions.

31. From Case I., which is simply an illustration of a well-known law of thermodynamics, it may be seen that the theoretical effective work obtainable from a given quantity of heat is, when Carnot's cycle and the same limits of temperature are employed, independent of the working fluid. At the same time, however, the component parts of the total work may vary very much, as is illustrated by the figures in Tables I. and II., or, more clearly, by the indicator diagrams, Plate I.

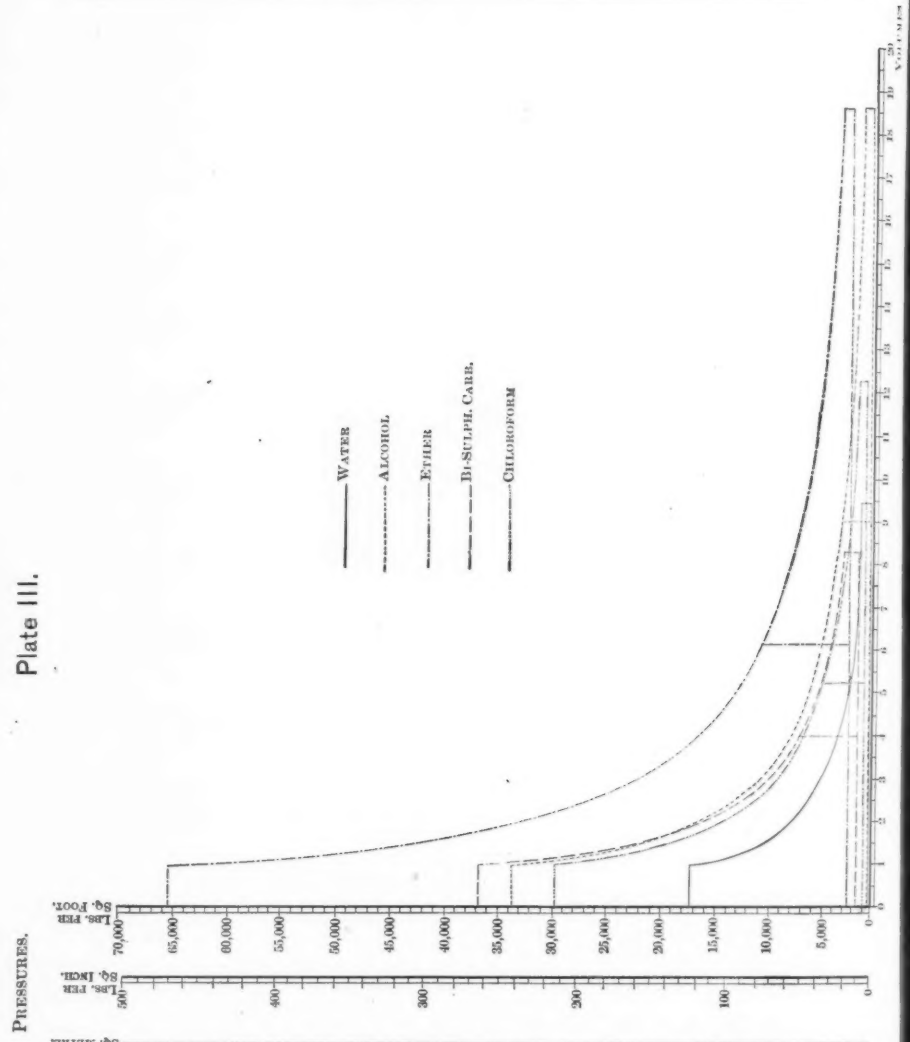
32. On comparing the efficiencies of the non-aqueous vapors in Case II. with the same quantities in Case III., we see that in every case, except that of ether, the figures are larger in the former than in the latter case. It would therefore seem, at first sight that the method we have taken of increasing the efficiency by reducing the ratio of expansion must fail. It must be remembered, however, that while, in the ideal case, expansion down to the back pressure is most efficient, there are certain practical considerations, such as condensation in the cylinder and friction of engine, which make a more limited ratio of expansion best. It is to this best ratio that we have tried to approximate in Case III., and hence the performance of engines built for working these fluids would agree more nearly with the results of this case than with those of Case II. It is for this reason that we consider the results in Case III. of more practical value than those of the case preceding it; and it may be seen that, *if we limit maximum pressure to that employed in the steam engine, steam is the most efficient fluid we can use.* The relative size of cylinder necessary to produce the same power which is represented by the letter M in Tables III. and IV., is smaller for steam than it is for the non-aqueous vapors when all have the same initial pressure.

Case V. resembles Case III. in having the same final pressures, but differs in having higher initial pressures in all cases except that of steam. This higher initial pressure, involving higher initial temperature, and consequently greater range of temperature, causes such an increase of efficiency of the non-aqueous vapors as to put them all above that of water, and to cause some doubt as to which would be the best working fluid, judged thermodynamically only.

As the most convenient method of deciding the question just raised, we may compare each of the vapors with that of water, showing their advantages and disadvantages.

The vapor of alcohol gives us 1.4 per

Plate III.




cent. more efficiency than steam, and requires a cylinder whose volume is only 0.853 of that of the steam cylinder to produce the same power. The disadvantages of alcohol are the high tension of the vapor, the great danger which arises from the ready inflammability of the hot liquid, and its cost.

The use of ether would give us a greater gain in efficiency (2.11 per cent.), and would require a still smaller cylinder (0.535 of that of steam), but it is open to the same objections as alcohol, and in a more marked degree.

The vapor of bi-sulphide of carbon gives a gain in efficiency of 3.71 per cent., and demands a cylinder 0.550 of that of steam. It, however, is not only open to

all the objections that have been stated against alcohol and ether, but it has two which are peculiar to itself, viz., its intensely disagreeable odor, and its power of rapidly corroding iron which comes alternately into contact with it and with the air.

The vapor of chloroform, which gives a gain of 3 per cent. efficiency, and requires a cylinder 0.761, the volume of that of steam, is not open to the objection of inflammability, but it has so high a cost that it is probably impossible that it can ever be used economically in competition with steam.

All the apparent advantages of the non-aqueous vapors may be gained in the steam engine by an increase of initial pressure; and, as the tendency of modern practice is in that direction, it seems certain that *none of the non-aqueous vapors will ever successfully compete with steam.*

## REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—*October 1st*, 1884.—Vice-President Wm. H. Paine in the chair. The following candidates were elected members: Burr Kellogg Field, Philadelphia, Pa; Charles Alfred Marshall, Johnstown, Pa.; Robert Imley Sloan, New York, N. Y.

Mr. H. Trueman Wood, Secretary of the Society of Arts, London, England, presented a short statement in reference to the International Inventions Exhibition, which it is proposed to hold in London during 1885. He expressed the desire of the management of the Exhibition that the engineers of America should know of this exhibition and aid in securing its success. It is one of the series of exhibitions which are in progress, that of last year being devoted to fisheries, and that of the present year to subjects connected with health and education. The Exhibition of 1885 will be devoted to apparatus, appliances, processes and products invented or brought into use since 1862. It is intended to illustrate industrial processes, and not to exhibit finished products unless required for full demonstration of a particular process. The Exhibition will be under the presidency of the Prince of Wales. The Chairman of the Executive Committee is Sir Frederick J. Bramwell, Vice-President Inst. C. E. Copies of a detailed prospectus were presented by Mr. Wood. The subject was referred to the Board of Direction for consideration.

The death on September 25th of Isaac Newton, M. Am. Soc. C. E., was announced.

Announcement was made that Messrs. L. B. Ward, E. B. Van Winkle and Amory Coffin had been appointed Censors to award the Norman Medal, and that Messrs. George S. Morison and D. Farrand Henry had been appointed on the committee to award the Rowland Prize.

A paper by F. P. Stearns, M. Am. Soc. C. E., "Experiments on the Flow of Water through a 48-inch pipe," was read. These Experiments were made on a pipe on the line of the Sudbury Conduit, used to carry water across a valley. The pipe was cast-iron, coated with Dr. Angus Smith's coal tar preparation.

## ENGINEERING NOTES.

Monster Russian Bridge.—It is reported from Russia that the question is being agitated of connecting Cronstadt and Oranienbaum by a bridge at a cost of £2,400,000. The structure is to rest upon granite pillars fixed by the caisson method, each of them protected from the action of the waves during the prevalence of south-west wind by an angular wall-like guard of stone. The bridge will be about five miles in length, and it is expected to be completed by 1889. When finished—if it is ever finished—it will consist of two parts, a railway and a foot-bridge.

The Severn Tunnel was begun in 1873 and is now approaching completion. It passed under the Severn where it is 2¼ miles wide. The length of the line is 7½ miles, 4½ miles being in the tunnel under the Severn. It is made almost wholly in rocks of trias and coal measure formation. The lowest part of the line is at 60 feet depth at low water, and 100 feet at high water. The work has been flooded on several occasions, much water being met with throughout the construction. The quantity of water now being pumped is about 19,000 gallons per minute. Other pumps are being erected which will enable 41,000 gallons to be pumped. The tunnel will be for a double line of way, and will be lined throughout with vitrified bricks set in Portland cement.

The Forth Bridge.—The contract for the bridge has been let for £1,600,000. The total length of the viaduct is about one mile and a half; the clear headway under the center is 150 feet above high water. Operations began in January 1883, and already about £370,000 have been expended. The main piers are all started; the minor and end piers are in an advanced state. For the superstructure the iron has been delivered. In one of the Fife piers the drilling of the rock had to be abandoned, a timber and clay coffer dam being constructed. The difficulty in the shallow rock foundation at the Forth much resembled Stephenson's when building the Victoria Bridge, the contractors treating it in much the same way. Forty-two miles of plates are required for the tubular compression. Finally the proper method was hit upon, consisting in bending plates hot, giving them a straightening squeeze afterwards when cold. No important modification has been made in the design. One change was made in attaching the superstructure to masonry, which consisted in securing it to one of four cylindrical piers in each group, and permitting a certain amount of sliding on others. The whole weight of the structure on the piers will cause friction between the surfaces of the upper and lower bed plates sufficient to prevent movement except in rare cases. Experiments have

proved that 56 pounds per square inch would be the highest wind pressure likely to be encountered.

## IRON AND STEEL NOTES.

TEMPERING STEEL BY COMPRESSION. — We have repeatedly alluded to the method brought forward in France by Clemandot for tempering steel by compression. Further details have been furnished lately by a report by M. Ad. Carnot to the Societe d'Encouragement. M. Clemandot's method consists in heating the metal so that it becomes sufficiently ductile and then submitting it during cooling to a strong pressure. He noticed that this treatment affected the structure of the metal in such a way that it acquired properties analogous to those brought out by tempering. The metal thus obtained differs considerably from steel simply cooled, by its finer grain, its greater hardness, and its greater resistance to rupture, particularly with certain grades of pretty high carbon steel. In these respects it approaches in quality steel tempered in water, without being identical with it. It has two different effects, almost simultaneously, an energetic and continuous compression, and a rapid cooling of the steel. The cooling is caused by the contact with the platform of the hydraulic press, and takes place much more rapidly than when the same piece is allowed to cool without being compressed. The remarkable results obtained by M. Clemandot are explained by the combined action of cooling and compression. The first, in its results, resembles the compression effected by hammering or rolling; the second, the effect of tempering by immersion. It has been urged that the piece of steel must be inclosed by a mold into which it fits exactly. It is, however, only necessary that the compression act upon two opposite faces. A square bar, whether straight, or curved to horse-shoe shape, need only be laid down flat and compressed between the two platforms of an hydraulic press. In order to obtain the best results, the cherry-hot piece of steel should be as rapidly as possible subjected to the pressure settled upon beforehand, ranging from 10 to 30 kilograms per square millimeter.

While the tempering process by immersion brings about an increase in the volume of the steel and a corresponding decrease in its density, the action of high mechanical pressure during the entire process of cooling tends to bring the metal back to its original volume or its normal density, thus preventing the creation of a state of intermolecular tension noted in tempered steel. Actual experiment has confirmed these theoretical deductions, so far as the resistance of the compressed steel to stress is concerned.

## RAILWAY NOTES.

IMPROVEMENTS IN THE PERMANENT WAY AND WORKS OF ITALIAN RAILWAYS—By F. BIGLIA.—This paper contains the results of the second of the three commissions upon matters relating to the Italian railways. The Berne International Conference, recommended that the international gauge should be changed from 4 ft. 8.5 in. to 4 ft. 8.69 in. This was objected to by the French and Italian delegates, because in France many of the principal lines have a gauge of 4 feet 9.08 inches, and in Italy the gauge is fixed at 4 feet 8.89 inches, a mean between the French of 4 feet 9.08 inches, and the German of 4 feet 8.5 inches. The Italian Commission agreed to accept the gauge proposed at Berne as soon as it should be adopted by the French Government.

*Foot Signals at Points.*—The commission decided that these are not to be considered as stopping signals, their object being to enable the station-men to see from a distance how the points stand, and to show the engine-driver upon what line he is traveling. There was a long discussion as to the color to be adopted for these, a red ought to be used exclusively for stop signals, but nothing was decided. These signals are to be limited to the points at the ends of stations, and to those giving access to large groups of good sidings.

*Level-crossing Barriers worked from a distance.*—The following are the decisions of the Commission in regard to these. A bell is to be fixed near each barrier, and rung before it is moved, to give notice to travelers. Barriers must be visible from the points at which they are worked, which must not be at a greater distance than 1,600 feet. Lights are not to be provided, except in special places. One man is not to have more than two distant barriers under his charge, in addition to his own gate, and the levers must be within 32 feet of each other. The barriers are to be placed parallel to the line, at a distance of 6 feet 6 inches from the nearest rail; there is to be a separate lever for each side of the line, and the barriers are to be constructed so that they cannot be opened and shut by passers by. They are to be weighted so as to close gradually in the event of the connection with the lever breaking. The use of these barriers is to be confined to unimportant roads and to single lines of railway upon which the traffic receipts are less than 35,000 lire per kilometer per annum.

*Three-throw Points*—It was decided to allow these to be used, but not upon lines traversed by express trains; the central line must be straight. They may also be used on express lines at stations where all trains stop. A system of double points, by means of which trains running in either direction upon either of two lines of way, can either keep their own line or be shunted on to the other, is permitted to be used in certain cases, but limited to slow lines and sidings.

*Attachment of Trolleys to Trains.*—One of the questions discussed was whether trolleys might be attached to trains by slip-couplings. It was objected that the attachment being necessarily above the center of gravity of the trolley, there is a tendency to turn it in a vertical plane round the front axle whenever this encounters the slightest resistance. On the other hand the plan is most useful for drawing heavy loads up steep inclines, for when the workmen have to push the trolleys themselves, they arrive at the place where they are going to work exhausted, and, which is worse, in a state of heat which exposes them to attacks of fever in unhealthy

districts. The Commission decided to allow the attachment to slow trains on lines having gradients steeper than 1 in 100.

*Traffic at Level Crossings.*—On the Italian lines there is generally a level crossing at each station, and as these are situated in populous places, they are the occasion of constant complaints from the inhabitants, owing to the length of time during which the gates are closed, either on account of the trains being late or during shunting operations. There are also frequent crossings in the open country. If it is proposed to substitute a bridge for a crossing, the necessary approach is objected to, especially in level districts, when the necessary gradient would limit the load which animals can draw. Besides this, owing to the station-sidings it would often be necessary to carry the road across the line at some distance from the station, and this would necessitate a long diversion. The time during which the gates are closed can be limited by the use of signals, but, on the other hand, it is impossible to run quick trains when the driver has always to be ready to stop at these signals. After some discussion, the Commission decided (1st) that in order to insure sufficient protection of level crossings at which it is important to limit the time of closing the gates as much as possible, they might be entered in the time-tables and treated like stations, and provided with disk signals and electric instruments to give notice when the trains are late; (2d) that at less important crossings it will be sufficient to provide telegraph communication with the nearest station; (3d) that on main roads crossing lines of heavy traffic, especially where the roads have steam trams on them, it is essential that bridges over or under the railway should be built, and, considering the interests involved, the cost may be divided between the railway and the public bodies which would benefit by the change. It must not be forgotten that the cost of gate-keepers will be saved.

*Ballast.*—Ever since the construction of railways was commenced it has been a disputed point whether the ballast should cover the sleepers or be laid level with their upper surface; the former system protects the timber from the direct rays of the sun, from sudden changes of temperature, from moisture, dryness, and frost, and gives excellent results in preserving the sleepers from decay. These advantages are, however, denied by some engineers, who consider that covering the sleepers makes them decay more rapidly, and increases the first cost of the line and the difficulties of maintenance.

The Commission came to the conclusion that though uncovered sleepers may be preferable in northern climates, it is necessary in Italy to completely imbed them in the ballast.

*Working strains allowed in Iron Roofs and Cranes.*—The working strain allowed in bridges in Italy is 3.81 tons per square inch, provided that the breaking-strain is not less than 20.32 tons, and the limit of elasticity 9.52 tons per square inch. Italy being entirely dependent upon foreigners for supplies of iron, it is found more economical to use Belgian iron, which will stand these tests, rather than stronger but more expensive material. For roofs the Commission fixed upon working-strain, 5.08 tons; breaking-strain, 22.86 tons per square inch, with 8 per cent. extension. Various methods have been suggested for limiting the weights lifted by cranes, among others Hohenegger's apparatus, which indicates the weight which is being lifted, and automatically prevents the lifting of weight in excess of that which the crane is designed to carry. The Commission determined to conduct trials with this apparatus.

There is annexed to the Paper a report upon lighting carriages with oil lamps.—*Abstracts of the Institution of Civil Engineers.*

## ORDNANCE AND NAVAL.

Re-arming the Navy.—About 400 of the new steel guns have been completed at the Royal Gun Factories, and these are nearly sufficient for the re-armament of the smaller ships of the Royal Navy. More than 150 of the new guns are of the 6-inch class of breechloaders, and seven-eighths of the whole are especially adapted for sea service. Large guns for the heavier ironclads are now in course of construction and all the guns now made being of the type described by Colonel Maitland in his recent lecture as the latest combination of all that is best in all the best systems, it is hoped that within a year or two the present deficiencies in the armament of the Royal Navy will be satisfactorily repaired.—*The Engineer.*

Torpedo Experiments in Bantry Bay.—Two experiments with fully charged Whitehead torpedoes have been made by two vessels of the Channel Squadron at Bantry Bay. The steam pinnace of the Minotaur discharged a Whitehead torpedo at a large rock at the head of the bay. The machine ran at a rate of 13 knots an hour, being loaded with a charge of 117 lbs. of gun-cotton. It was adjusted to run 400 yards, and was discharged when the pinnace was about 300 yards from the rock. The torpedo, a 16-inch one, weighed 600 lbs. It struck the face of the rock 7 feet from the surface and threw up about 30 tons of water to a height of 300 feet, also several pieces of rock. The result of the experiment was considered most satisfactory, the more so as the rock was very unfavorable for the purpose, containing a number of crevices and presenting no even surface such as a ship would. The base of the rock was nearly destroyed, large pieces being disconnected. The second experiment, conducted by the Neptune, was not successful; the machine did not go fair and missed. It ran its full course of 400 yards and sank. During the stay of the fleet numbers of successful experiments have been conducted with submarine mines and stationary torpedoes.

## BOOK NOTICES.

Publications Received.

International Health Exhibition Library Catalogue. London: William Clowes & Sons.

Monthly Weather Review for August. Washington: Government Printing Office.

Papers of the Institution of Civil Engineers:

No. 1892.—The Ashti Tank. By Charles Toler Burke, M. Inst. C. E.

No. 1985.—On Galvanic Action Between the Various Irons and Steels in Sea Water. By Thomas Andrews, F. R. S. E.; Assoc. M.I.C.E.

No. 2014.—Water Supply in Peru and Distilling Apparatus at Iquique. By Charles Malcolm Johnson, R. N.; Assoc. M. I. C. E.

Abstracts of Papers in Foreign Transactions and Periodicals.

No. 2008.—The New Harbor of Trieste. By Friedrich Bornches.

No. 2015.—Old Water Supply of Seville. By George Higgin, M. I. C. E.

No. 2010.—The Area of Sluice Opening for a Tidal Canal. By James Henry Apjohn, M. I. C. E.

No. 1972.—The Passage of Upland Water through a Tidal Estuary. By R. W. Peregrine Birch, M. I. C. E.

No. 1964.—A Dioptric System of Uniform Distribution of Light. By Alexander Pelhorn Trotter, Assoc. M. I. C. E.

No. 2000.—Wood Pavement in the Metropolis. By George Henry Stayton, Assoc. M.I.C.E.

London: Published by the Institution.

A Treatise on Steam-Boiler Incrustation. By Charles Thomas Davis. Washington: Industrial Publishing Co.

There is no doubt of the importance of the subject of this practical treatise. The author has endeavored to furnish "reliable information as to the various compounds and mechanical apparatus employed for the prevention of boiler incrustation," and has achieved a fair success. The book presents but little improvement upon former works on the same subject, Rowan's for example, so far as explaining the causes and cure of the evil are concerned, but is much fuller in its description aided by diagrams of different methods.

On the other hand, the author rests content with mere enumeration and brief description of the various processes. Of their relative efficiency the reader is left to draw his own inference.

A Treatise on Ore Deposits. By J. Arthur Phillips, F. R. S. London: Macmillan & Co.

That this treatise will be accepted as a standard authority may be safely assumed. The previous works of the author have earned for him the reputation of a careful and industrious contributor to the literature of metalliferous deposits. His "Manual of Metallurgy," and "The Mining and Metallurgy of Gold and Silver," are well-known books of reference in all libraries of general technical literature.

The first part of the new treatise is devoted to "ore deposits in general." This part may be read with profit by students of geology who have no interest in hunting ores. The various ways in which the accumulations of valuable metallic compounds have been brought about are discussed and fully illustrated by diagrams.

Beginning with superficial deposits, the author describes their accumulation under the mechanical action of water and the chemical reaction which has caused precipitation out of solutions.

The origin of Stratified Deposits is next considered, and the theories of precipitation with or without subsequent metamorphism, are clearly set forth. The dissemination through sedimentary beds receives its full share of attention.

The next section, Unstratified Deposits, would of itself make a valuable handy book for the mining engineer. It is devoted to the description of the so-called mineral "veins" of all kinds. In succession are presented Modes of Occurrence of True Veins, Intersections and Faults, Structure and Composition, Distribution of Ores in Lodes, Out-crop of Lodes, Grouping and Sequence of Minerals in Lodes, Influence of Depth, Influence of Country Rock, Age of Mineral Veins, Genesis of Mineral Veins, Theories respecting the Formation of Mineral Veins, Segregated Veins, Gash Veins, Impregnations, Contact Deposits, Fahlbands, Chambers or Pockets. Diagrams are abundant throughout.

Part Second describes the "Ore Deposits of the Principal Mining Regions," and is divided into shorter sections each of which deals with the mines of a country. In addition to the geological and physical features of the mining regions there is added in many cases the history of the earlier operations and the statistics of the later ones. It is not often that a book bearing a title suggesting only a technical value contains so much varied and in every way valuable information.

A Treatise on Chemistry. By H. E. Roscoe, F. R. S., and C. Schorleunner, F. R. S. Vol. III., Part II., 8vo, cloth, New York: D. Appleton & Co.

The second part of the volume on Organic Chemistry of the work which has been described as "the finest systematic treatise on modern chemistry," has just been published.

New discoveries are continually extending the confines of organic chemistry. A few years ago, all that was known concerning it could be summed up in a few brief paragraphs, but the magnificent discoveries in the department of dyes, the wonderful development of synthetical chemistry have led to increased activity in this branch of chemical science, so that to-day a description of its compounds requires a space equal to, if not greater than, that of mineral chemistry.

A full review of the contents of this book cannot be attempted here. A few remarks on this point, however, will not be out of place. Among the uric acid compounds, descriptions of caffeine and theobromine will be found. The similarity of their composition to that of certain of these bodies suggests that the preparation of these so-commonly used alkaloids from guano, may be possible.

Glycerot, generally called glycerine, is fully described. Its preparation, its properties, its derivatives (including nitro-glycerine), and its applications are thoroughly discussed. We find

that when "it is allowed to stand in a sufficiently concentrated condition at 0° C. (32° F.), crystals form after some days." Its boiling point is stated to be 290° C. (554° F.)* The carbo hydrates are treated quite fully, cane sugar naturally receiving most of the attention. Grape sugar is not neglected, but sorghum sugar receives scant justice and is dismissed with a paragraph. With cellulose, its explosive derivative gun-cotton, collodion also, and the details of paper-making come in for consideration.

For the benefit of those who desire more detailed information, foot notes containing references to original memoirs are given on nearly every page. Clear, beautiful illustrations, engraved especially for this work, are inserted where necessary.

In 1877, nearly eight years ago, the first of this series appeared, and the present volume, completing the work, fully sustains the promise of that initial portion.

The distinguished authors, Prof. H. E. Roscoe and Prof. C. Schorleunner, of Owens' College, Victoria University, Manchester, England, deserve our thanks and congratulations for having brought to a successful termination so beautiful and perfect a work on chemistry.

It is not excelled by any similar treatise in the English language.

THE ATTACK AND DEFENCE OF COAST FORTIFICATION. By CAPTAIN EDWARD MAGUIRE, Corps of Engineers of the U. S. Army. Published by D. Van Nostrand, 23 Murray Street, New York City.

From the earliest times the problem of the defence of its coast has occupied the attention of every nation having a border on the sea. In every country the seaboard towns are the main sources of the nation's wealth. Consequently the defence of these towns from destruction or occupation by an enemy is a matter of interest to every inhabitant who has anything at stake, whether it be dollars or whether it be national pride. The whole history of the attack and defence of coasts is but a record of progress and development; progress in the art and science of war and development of the applied means of attack and defence. The close of the war of the rebellion found the United States the best fortified country in the world with the finest forts and the best guns. But the long and valuable experience of that war led to much scientific study of both ships and forts. The European nations have devoted much time and money to the problem of guns-afloat and guns-ashore. During the many years of costly experiments guns grew in size and power, and ships' armor increased in might and strength, and at the present time we have huge armored floating citadels like the Italian "Duilio." But ships must manœuvre and for that purpose they must possess certain very essential qualities—flotation, stability and sailing capacity. These qualities put a limit in the size of the ship and hence on the weight of its armor and armament. That limit has been reached, and to-day the problem of the attack and defence of coast-fortifications is susceptible of solution and the principles upon which that solution depends are simple in character and of application. The little book now before us aims at an exposition of these principles. It treats of naval fighting means, giving a description of the different kinds of war-ships, as well as discussing the operations of a fleet against coast-fortifications; it devotes much attention to coast-forts and batteries; obstructions and sea mines; accessory defences, the armament of batteries; the general measures of coast defence, and closes with an example of modern coast-defence. It contains many illustrations. The writings of the great European nations as well as of our own have been called upon by the author for material for his work. What originally commenced as a series of professional notes he has developed into a book. The introduction gives an insight into the author's object in publishing the work. It reads as follows:

"As a rule the periodical military literature, as well as the text-books, treat the above mentioned subjects only by piece-meal, and usually only with reference to secure particular work which the author at the time has on hand. Under such circumstances one is forced to wade through a great mass of material in order to garner that which is worth knowing. This is a tedious and often impracticable process. Books are expensive, professional libraries scarce; and a knowledge of French and German, at least, is almost indispensable to the student.

"Again: a great many of the text books go too much into the details of old forms, and devote too much attention to dead issues. The tendency is to force the young man to spend part of his life in a past age; that is, to encumber his mind with a mass of information which even his grandsire would have been glad to have forgotten."

There has of late years grown up the idea that torpedoes alone will constitute a sufficient defence for this country. Congressmen make long speeches in favor of torpedoes and refuse to vote an appropriation for forts and guns. Even some professional soldiers have been carried away with the defence of our harbors by means of submarine mines alone. The very uncanniness of the torpedo and the general ignorance of the masses of the true nature of submarine mines has invested them with a species of awe and admiration. The author of the book is an advocate of forts and big guns and closes his discussion of submarine mines as follows:

"Submarine mines can in no case replace guns, especially as their own security depends upon guns. Guns and passive obstructions may constitute an effective defence, but submarine mines alone—never. It must be distinctly borne in mind that a submarine mine has but one life, and, having been once exploded in action, it cannot be replaced; while the activity of the guns is limited only by the supply of ammunition.

"Submarine mines, more than any other weapon, call for experience, skill, training, and the closest attention on the part of those operating them. From the very nature of things they must be operated by "the few;" while guns can be fought by "the multitude," and without

* See p. 173, August, 1884, issue of this magazine.

very great training. It is a well-established principle that all engines-of-war should be as little complicated as possible, and as free as possible from delicate parts; therefore the main defence should never be left to submarine mines, which any one of a number of unforeseen accidents may render useless, and which can be operated by only a few men whom it would be difficult to replace in time of action."

While the book is written especially for the professional soldier it should not be without interest for every thinking citizen. There is very little of the purely technical in it, and as a whole it is easy of comprehension. The publishers have done their work well. The volume is a handsome one, clearly printed, and elegantly bound.—*Commercial Advertiser, Buffalo.*

A Practical Treatise on Electric Lighting. By J. E. H. Gordon, B. A., M. S. T. E., etc. New York: D. Appleton & Co. 1884. pp. 228. Price $4.50.

This book is from a pen which has already achieved a reputation by the production of an excellent treatise on "Electricity and Magnetism," doubtless known to many of our readers. In his first work, however, the author wrote from the standpoint of the physicist, while in the present work he writes rather from the standpoint of the inventor. This change of the author's position relatively to his theme is, as might be anticipated, detrimental to the book to a great extent.

It is undeniably to the credit, as much as we trust it may be to the profit, of the author to have sought to lend a hand in the practical development of the art of electric lighting. But in turning inventor he has placed himself in such a relation to this art that his judgment must inevitably suffer from the changed perspective. He is no longer sufficiently removed from the whole field to be able to see things as "outsiders" see them. What is immediately near him seems to grow in size, while everything else fades into insignificance. The partiality of the author to his own or his friends' methods would not be so objectionable were it separable from a certain indifference and prejudice which obscure or ignore the methods of others.

The book is divided into twenty-one chapters, but one of these (Chapter XIX.—"Central Station Lighting") is merely laid out, the five lines under this head being intended as a prospectus of a "long chapter" which is to be inserted there in a future edition, the author not being prepared, "for various reasons," to write it for the present edition. We venture to say that if there had been any central station on the "Gordon" plan to describe, one of these various reasons at least would have been removed. As for what has been done by Edison in central station lighting by incandescence, and by Brush and others in arc lighting, it was probably not worth mention.

Of the twenty filled chapters, about ten are extremely good, and the rest as extremely bad. The good chapters are those in which the principles underlying the art of electric lighting are analyzed and elucidated. In these chapters there is no evidence, at least, that the author has an axe of his own to grind. We think so well of these portions of the work that we regret that the author did not publish them separately with the excellent tables contained in the appendix, and, by so doing, give us a most excellent treatise on "The Principles of Electric-Light Engineering." Chapter I. (Principles of Artificial Lighting), Chapter II. (Conversion of Electric Currents into Heat), Chapter III. (Electrical Units, Heat, Work, etc.), and Chapter IV. (Rules for the Resistance of Divided Circuits) fulfill their respective missions in a very creditable manner, making intelligible much that has failed to become plain in the hands of other writers. We might say the same of Chapter IX. (Magnets and Electro-Magnetic Induction) and Chapter X. (General Principles of Electrical Generators), and also of Chapter XVII., though in this case the author has sacrificed much of the clearness for the sake of brevity. Chapter VIII. (Carbons for Arc Lamps) is one of the most interesting and valuable in the book, especially so since there is little said in other books on this subject. Chapter XI. (On Designing Dynamos, and on their Mechanical Construction) is that to which we feel disposed to award the palm for excellence. We believe that to many this chapter alone will be worth the price of the book, for it gives many practical hints and methods, and, above all, it teaches common sense. If we add to these Chapter XXI., which is merely a reprint of the "Rules for the Prevention of Fire Risks," drawn by the Society of Telegraph Engineers, and the Appendix, which contains a number of very useful tables, we shall have mentioned about all that can pass without adverse criticism. The chapters not yet named are those which are wholly or mainly descriptive, and they all suffer from the illusion of perspective which we have explained above. We fear that the unwary student will often get from these chapters impressions and prejudices that were better avoided. What concerns Mr. Gordon or his friends is very fully described, even to obsolete forms and to minute details. As for other inventors and inventions, they are either ignored altogether, or else passed over with descriptions too meager, too careless, we might say, to be reliable and useful.

In Chapter V. there is not even a mention of the Deprez-Carpentier current meters, after which were patterned those of Ayrton & Perry, which are so fully described. In Chapter VI. the lamp most extensively used the world over—the Edison lamp—receives the least attention, namely, one page with one illustration, which follow some ten pages, including fifteen plates and illustrations, devoted to the "evolution" of the Swan lamp. In Chapter VII. the author shows his deference for his friend, Mr. R. E. Crompton, by telling all he can about his lamp, and as little as possible about any others. Four forms of Crompton arc lamps are described at length, with numerous figures, and only two other lamps, the Serrin and the Brush, are referred to. Chapter XII. (Some Typical Alternating Current Machines) contains a "reference" to the machines of De Meritens and Siemens, a "criticism" of the Farranti machine, and a "description" of the Gordon dynamo.

Chapter XIII. (Some Typical Direct-Current Machines) begins with a full description of the Crompton-Burgin machine, after which come rather inadequate descriptions of the Brush-Siemens and "large" Edison machines. The author doubtless imagines he has given his readers "a representative selection," for he says in the preface: "In describing machines and lamps I have not thought it necessary to describe many, but have selected those which are typical of different classes." Chapter XIV. (Regulation of Machine) is evidently intended to force a conclusion, and this conclusion is printed in italics at the end of the chapter. Briefly, this conclusion is: *The true secret of successful regulation is Mr. Gordon's own plan.* Mr. Gordon's plan of regulation does not contemplate by compound winding, and of course he "doubts if compound winding, in spite of its apparent simplicity will be much used in the future, except for small machines!"

Mr. Gordon sees no earthly use in storage batteries, and Chapter XVI. is devoted to the proof of that doctrine. These details are sufficient to show that the descriptive portions of this book are to be taken with a rather large grain of allowance for the author's partiality and prejudices—a personal equation which undoubtedly would not appear if the author were not identified with the art as an inventor. As for the rest of the book, it is, as we have said already, most excellent, and it will perhaps bring the book into favor in spite of the faults we have just noted.

THE THEORY OF DEFLECTIONS AND OF LATITUDES AND DEPARTURES—WITH SPECIAL APPLICATION TO CURVILINEAR SURVEYS FOR ALIGNMENTS OF RAILWAY TRACKS. By ISAAC W. SMITH, C. E. 16 mo., morocco tucks. Price, $3.00.

Geometer is the Greek word for a land surveyor or measurer, and, at the present time, geometry would seem to be all Greek to a large portion of such geometers. Chiefly because of the false definitions of quantities given in the text books used in schools and colleges, on account of which graduates in mathematical courses, on attempting to reduce their theories to practice on any other than a paper field, are confronted with quantities of which they have had no previous knowledge, and are unable to solve the simplest problems beyond the compu. tation of the sides and angles of a triangle.

It is claimed by authorities in geometric science that their conclusions are based on definitions easily understood, and on self evident axioms and postulates, but any one of ordinary common sense, who will trust to his own judgment and not be overawed by the weight of authority, will find by examination that their premises are often in direct opposition to their conclusions.

An angle, for instance, is defined by Euclid (see Playfair's translation), as "the inclination between two straight lines which meet and are not in the same straight line;" by Legendre as "the quantity, whether greater or less, by which two straight lines which meet depart from each other as to their positions," and by Davies as "the space, or the divergence, between two straight lines produced to intersection;" and from these widely different definitions, as a relation between two straight lines which *are not* in the same straight line, they each deduce the same elementary proposition, that the lines *are* in the same straight line when the angle is 180 degrees.

From these definitions it will therefore follow that the inclination, or the departure, or the space, or the divergence, between two lines is twice as great when they are portions of the same straight line as when they are perpendicular, or at an angle of 90 degrees.

This absurd conclusion, that the angle between two straight lines comes into existence only when they are produced to intersection, has been the source of countless blunders and much useless waste of money, especially on railway surveys, on which it is necessary to calculate the sign and magnitude of each tangential deflection on the alignment.

In proof of this might be cited a circular issued by the chief engineer of an important transcontinental road, instructing his assistant engineers to produce always to intersection tangent lines from the extremities of each circular arc; nor is this in any way a singular instance of supermathematical stupidity. In a work for instance, on the elements of plane surveying and navigation, by the late Mr. Davies, professor of mathematics in the United States Military Academy of West Point, after defining an angle as the portion of a plane between two straight lines which meet at a common point, he gives four elaborate rules for determining the angle between two straight lines from their bearings and adds, in a note, that "the above principles are determined under the supposition that the two courses are both run from the same angular point, hence, if it is required to apply them to two courses run in the ordinary way, as we go around the field, the bearing of one of them must be reversed before the calculation is made."

In application of these rules it is then stated that, when the bearings of two courses are N 39 W and S 48 W, the angle between them is 93 degrees when measured from the same angular point, and 87 degrees as "we go around the field." The same confusion of ideas exists as to the natures of other trigonometric quantities.

A ship sails 100 miles in a direction 30 degrees right or left of a north direction; the departure at right angles to a north line, is a half mile to the mile, and has the same sine with the bearing, and this rate of departure, equal to five tenths, is the sine of the bearing, and the departure in 100 miles is 100 times the sine of 30 degrees and equal to 50 miles.

But turning to Legendre it will be found that the sine is the perpendicular let-fall from one extremity of an arc upon a radius through the other extremity, and hence it would follow that a sine is not a constant quantity, but varies with the radius of the arc by means of which it is measured.

Plane trigonometry, or the problem most frequently recurring in plane trigonometry, is the determination of the relative positions of points, or the direction and distance from one point to another, and it is singular that direction is seldom or never considered or even alluded to in text books.

A direction may be defined either as from one known point to another, or by the bearing or deflection, right or left, from some known direction. The relative position of two points may also be defined by the difference of their co-ordinate distances from two axes of known directions or, when the axes are rectangular, by the differences of their latitudes and departures.

The deflection from any direction to the same direction again is equal to 360 degrees; if the deflection from a direction BA to a direction B C is 180 degrees, A, B and C are on the same straight lines; the total deflection from one direction to another is the algebraic sum of the partial turns made in making the deflection; the departure of a line is the perpendicular distance, right or left, to the terminal point from an axis of given direction through its initial point; the sine of the bearing from the given axis is the rate of departure, and the sign of the sine and departure is the same with that of the bearing; the departure of the closing line from the initial to the closing point of a series of lines is the algebraic sum of the departures of the several lines composing the series. This is a brief summary of the principles of plane trigonometry, and the quantities are the same by the rough calculation of which the hunter or explorer can approximately determine the direction and length of the closing line from his starting point.

The theory of latitudes and departures has been long in use in plane surveying and navigation, but the theory of deflections, although applied to some extent on railway surveys, has not been reduced to a mathematical system. The object of the work is the application of these theories to the solution of problems in curvilinear surveys for alignments of railroad tracks, and it contains, besides the strictly mathematical propositions, the solution of all classes of problems generally presented in such works, and of many which, although of constant application, have hitherto been solved by the process known among surveyors as fudging.

Many of the propositions are not new, but they are derived by an original process, and based on the true nature of trigonometric quantities, and are an extensive experience in all classes of surveys in the Eastern States; in Mexico, and on the Western Coast, in the service of the Northern, Southern, Central, and Oregon Pacific railroads, in yard work and in the several capacities of leveler, transitman, assistant, Division and Chief Engineer, and on reconnoissances, preliminary and location surveys, as well as on construction.

Surveying does not require a high order of engineering talent, but what must be done should be well done, and few can realize the great and useless expenditures by men who can compute without understanding the quantities computed, or who understand their quantities without the ability to compute.

## MISCELLANEOUS.

M. Jacquelain has endeavored to procure a pure carbon for electric purposes that should be as hard and as conductive as gas carbon. He first takes gas carbon, which he submits to four processes: (1) Treatment with dry chlorine at a red heat for thirty hours; (2) treatment with hot alkali for about three hours; (3) immersion in hydrofluoric acid—one to two of water—at a temperature of 15 deg. to 25 deg.; (4) carbonized by heating strongly in the vapor of a high boiling hydrocarbon, for commercial purposes gas tar will do well. All these operations may be performed after the carbon has been cut into sticks. By these processes, which do not seem to be new in any particular, the *Scientific American* says, the impurities have been reduced to a minimum, and a good, pure carbon is obtained.

On the Preservation and Use of Beechwood for Railway Sleepers.—By Claus.—The use of railway sleepers of beechwood has hitherto been very limited. In Germany only about 1 per cent. of the sleepers is of this wood, and in Austria 3 per cent., although large beech forests are available in both countries. The slight durability of ordinary beech sleepers is the chief reason of this; their life is reckoned at two and a half to three years, while oak will last fourteen to sixteen, and fir seven to eight years. The best method of preserving beech sleepers appears to be impregnation with creosote. Prepared in this way the average durability of the wood for railway purposes appears to be about eighteen years, while chloride of zinc only preserves it for fifteen years. Sleepers impregnated with sulphate of copper or sulphate of barium had to be replaced after four or five years. In many places the expense of impregnated beech-wood is so much less than that of oak, that it might be used with great advantage were it not for the peculiar manner in which some beech sleepers have been observed to give way under sudden strain. In such cases the exterior of the wood appears perfectly sound, while the heart has become rotten and affords no hold for spikes or bolts.

In France the proportion of beech sleepers is much larger than in Germany; they are chiefly impregnated by Blyth's method, by which each sleeper absorbs about 22 lbs. oil of tar, while in Germany 36 lbs. of creosote are injected. The French method does not appear to remove the organic matters, which are liable to decomposition.

In Germany Rutger's method is in use for preparing these sleepers. They are gradually raised to a temperature of 130° Centigrade, and dried for at least four hours, until they cease to give off vapor and are completely warmed throughout. They are then removed, on the same trucks upon which they have been dried, to the creosoting apparatus. This consists of a horizontal cylinder with hermetically closed doors in which a partial vacuum is produced and maintained for half an hour. The warm creosote is then allowed to enter the cylinder, and the whole is subjected to a pressure of 100 lbs. per square inch for one hour. Before injecting the creosote it is advisable to extract by boiling so much of the sap from the timber as is possible. This should be done while the wood is new and before the sap has begun to ferment. After this operation the sleepers must be allowed to dry for two or three months. Beechwood prepared in the above manner appears to be well suited for railway sleepers.—*Dingler's Journal.*